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WINTER TESTING AND PASSENGER DEMONSTRATION OF WCSS RAILBUS ON CN LINES

BY

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17. Abstract The project had as its objectives the operation of the Winnipeg Coach Sales and Services (WCSS) Railbus on the INCO and CN railway lines in order to accumulate operating experience under winter conditions, gain acceptance of the modified vehicle by CN Rail and the Canadian Transport Commission (CTC) and operate a non-revenue passenger demonstration service for two months on the Thompson, Thicket Portage, Pikwitonei route in northern Manitoba. The WCSS Railbus is a 1963 Flyer highway bus modified to incorporate rail wheels and other equipment for operation on railway lines.

Considerable testing was carried out on the INCO railway line and modifications were made to the vehicle to meet CN and CTC requirements. A number of equipment failures necessitated time-consuming repairs, resulting in the two weeks of non-passenger tests being carried out on the CN Line in late April and early May 1986. Two separate weeks of non-revenue passenger service were undertaken during the last weeks of June and August. A wheel fatigue failure led to premature discontinuance of the service and a detailed examination of the wheel design. An investigation report by TTL recommended wheel redesign and test. The fact that the redesign, test and modification costs would be prohibitive, relative to the additional data that could be gained, resulted in the program being terminated by Transport Canada.

A total of 4960 km of operation was accumulated during the program. With the exception of the wheels, which need redesign to prevent fatigue failures, the results indicated that the railbus concept was viable and that safe operation was possible.

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17. Résumé Ce rapport concerne le programme d'essais du railbus fabriqué par la Winnipeg Coach Sales and Services (WCSS) à partir d'un autobus Flyer, sur les lignes appartenant à la INCO et au CN. Ce programme visait à éprouver le matériel en exploitation hivernale, à le faire approuver par le CN et la CCT (Commission canadienne des transports) dans sa version modifiée et à lancer un programme de démonstration de deux mois pour le transport de passagers non payants, sur la ligne reliant Thompson à Thicket-Portage et Pikwitoneau, dans le nord du Manitoba. Ce railbus est un autobus Flyer modèle 1963 converti à la circulation ferroviaire grâce à l'installation de roues à boudins et d'autres équipements.

Les essais intensifs effectués sur la ligne de la INCO ont montré la nécessité d'apporter certaines modifications visant à rendre le véhicule acceptable par le CN et et la CCT. Un certain nombre de pannes ont nécessité des réparations onéreuses en temps et en argent et ont eu pour effet de retarder le programme d'essais sans passagers qui s'est finalement déroulé fin avril, début mai 1986. Le programme de démonstration, auquel le bris d'une roue a mis prématurément un terme, a eu lieu fin juin et fin août 1986. Le rapport technique du contractant sur cet incident a préconisé la réétude des roues suivie d'autres essais. Pour sa part, Transports Canada se rendant compte que le coût de la réétude, des essais et des modifications serait prohibitf et qu'il n'y aurait aucun avantage supplémentaire à reprendre le programme, il a décidé d'y mettre un terme définitif.

Ce programme, qui s'est déroulé sur l'équivalent de 4 960 km, a montré que, exception faite du bris de roue nécessitant la réétude de ces organes pour en améliorer la résistance à la fatique, le railbus était un matériel viable et sécuritaire.

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SUMMARY

A Western Flyer highway bus was converted for operation on railway tracks by Winnipeg Coach Sales and Service (WCSS) Ltd. This vehicle was intended to serve as a test vehicle for evaluation of related engineering design concepts, addressing institutional and regulatory issues, and assessment of the overall feasibility of railbus operations in northern remote communities.

Previous Testing Program on INCO Line

The vehicle was subjected, in an earlier test program already reported ("Testing of the WCSS Railbus on the INCO Railway Line", TP7414E, Dec. 1985), to an exhaustive series of tests carried out on the INCO Railway Line in Thompson, Manitoba, over a period of three months in 1985. The tests had the major objectives of accumulating 3,000 km of operational experience; gaining acceptance from the Canadian Transport Commission (CTC) and Canadian National Railways (CN) for non-passenger-carrying test operation on the CN line between Thompson, Thicket Portage, and Pikwitonei; and, establishing the maximum safe operating speed on both tangent and curved track.

During the course of these earlier tests, 3347 km of operation were accumulated. Tests carried out evaluated stability, curving, switching, braking and operation of the various auxiliary systems including the turntable. The tests were generally successful and the vehicle proved to be capable of sustained safe speeds of up to 90 km/h. Vehicle ride was judged to be "just satisfactory" on the British Rail Ridemeter scale. Wheel and bearing life was judged to be satisfactory for demonstration operation. Interior noise was a problem and was reduced from 93 dB(A) to 87 dB(A) by various modifications. The one major hardware failure in the program was the turntable, which required strengthening and rework after 50 cycles of operation. In general, the rail-related modifications were successful. The vehicle proved to be unreliable, however, largely as a result of its age and modification history. Recommendations were made for improvements to increase reliability.

Winter Testing and Demonstration Program

The program for winter testing and passenger demonstration, which is the subject of this report, had as its objectives the operation of the WCSS railbus on the INCO and CN railway lines in order to:

a) accumulate operational experience under winter conditions in advance of passenger operation,

b) gain acceptance by CN Rail and by the Canadian Transport Commission (CTC) for operation in passenger service on the CN Thompson-Thicket Portage-Pikwitonei line,

c) operate the railbus over a period of 2 months in a non-revenue passenger demonstration service.

SUMMARY CONT'D

As a result of the recommendations provided in the previously referenced report, a number of modifications were made to the vehicle with the intention of improving its operability under winter conditions. These modifications included: installation of engine starting aids; use of the correct grades of winter lubricants; fuel system and air system filter improvements; modifications to the deadman switch; turntable and hydraulic winch; and installation of some driver comfort features.

These modifications and overall vehicle performance were then assessed during two months of testing carried out on the INCO railway line under severe winter weather. A number of equipment failures, the most significant of which involved the turntable, necessitated time consuming redesign and repairs which resulted in substantial program delays.

Following rectification of the failures, a total of 1709 km of troublefree operation was achieved during which the winterization features and turntable were found to operate satisfactorily down to a temperature of -30°C. The only exception was the emergency heater which had an inadequate heat output.

The winter test period on the INCO railway line was followed by an assessment of the vehicle by CN and CTC which resulted in a series of tests of specific features of the vehicle. The following tests, witnessed by CN officials, were carried out:

- Turntable Operation
- Vehicle Stability
- Ride Quality
- Curving
- Braking
- Deadman Control
- Towbar Operation
- Parking Brake
- Speedometer
- Headlight
- Horn
- Classification and Marker Lights
- Emergency Equipment
- Flags
- Clearance Envelope
- Rerailing Winch
- Signal Activation

These tests resulted in the following modifications: addition of safety retaining pins to the towbar; relocation and calibration of the speedometer; addition of a decal to the parking brake; increase of headlight range; addition of third tone and a separate air reservoir for the horn; removal of automotive (original) marker lights; identification and relocation of emergency equipment; and addition of an illuminated identification number.

SUMMARY CONT'D

Following these modifications, the vehicle was accepted for non-passenger operation on the CN line.

The non-passenger tests were carried out as a realistic simulation of the later passenger operation. A CN crew was trained to operate the vehicle and a TTL employee accompanied the vehicle to make observations. A complete round trip from Thompson to Thicket Portage and Pikwitonei took 5 hours. Approximately 1903 km of operation was achieved without incident in the period 27 April to 11 May 1986. It was concluded that the vehicle could be successfully operated in passenger service on the CN line by CN personnel. Following correction of some minor deficiencies, the vehicle gained approval by CN and CTC for operation in a limited non-revenue demonstration passenger service.

Passenger demonstration service was carried out during June 26 to 28 and August 26 to 30, 1986. A total of 9 round trips, each of 190 km, were carried out. After the initial week, the three man CN crew was reduced to two men. Acceptance of the vehicle by the public was excellent, and potential passengers were often turned away due to limited seating capacity. With the exception of the wheel failure on 30 August, there were no operational problems of any kind. On Saturday, 30 August, the left front wheel of the vehicle failed while in service. The vehicle was brought to a halt safely and the 14 passengers and crew were returned to their original destinations. TTL investigated the failure and recommended wheel redesign and test. Concluding that the redesign, test and modification costs would be prohibitive and that little additional evaluation data could be gained from continuing the service, Transport Canada terminated the program.

In all, a total of 4,960 km of operation was accumulated during the program and the following conclusions were drawn based on the tests and analysis carried out.

- The added features to meet the requirements of CN Rail and the CTC authorities improved the vehicle's serviceability, reliability, performance and measured level of passenger and driver comfort.
- The operating rules, practices, and procedures employed during the tests created a safe environment for the operation of the WCSS railbus on CN lines.
- The modified turntable design proved to be reliable and safe for regular vehicle operation. After rework and strengthening, the turntable was tested in cold weather conditions and it performed satisfactorily at -40°C.
- The emergency heater proved to be inadequate.

SUMMARY CONT'D

- The degree of controllability of both normal and emergency (dead-man) braking and acceleration was extremely good by rail vehicle standards as both foot-operated controls have retained the bus feature of continuous variability. This enables the driver to stop wheelspin or sliding very quickly.

- Redesign of the railbus wheels and retesting of the vehicle would be required before any further passenger demonstration could take place.

- The vehicle was found to be suitable for a limited passenger demonstration in remote service operation.

- The results indicated that the railbus concept was viable and that safe operation was possible.

- Further development of a "railbus specific" category of vehicle regulatory requirements is required to take into account the differences between remote service railbus operation and conventional operation with locomotives and coaches.

SOMMAIRE

An autobus Western Flyer a été converti en véhicule ferroviaire par la Winnipeg Coach Sales and Service Ltd. (WCSS) et soumis à des essais visant à évaluer le concept retenu, vérifier les aspects organisationnels et réglementaires du service envisagé et évaluer la faisabilité générale d'un service railbus dans les régions septentrionales isolées.

Essais sur la ligne de la INCO

Dans le cadre d'un programme d'essais ayant fait l'objet du rapport intitulé Testing of the WCSS Railbus on the INCO Railway Line, TP 7414E, décembre 1985, ce véhicule a été soumis à une batterie d'essais d'une durée de trois mois en 1985, sur la ligne de chemin de fer appartenant à la INCO, à Thompson (Manitoba). Les objectifs du programme étaient les suivants: parcourir au moins 3000 km, obtenir l'autorisation de la CCT et l'aval du CN pour une exploitation expérimentales sans passagers sur sa voie entre Thompson, Thicket-Portage et Pikwitonei et, enfin, déterminer la vitesse maximale de sécurité en courbe et en alignement.

À la fin de ce programme, le véhicule avait parcouru un total de 3347 km, et avait été évalué sur les plans de la stabilité, de ses caractéeristiques d'inscription dans les courbes et de passage sur les aiguillages, de ses performances en freinage ainsi que du fonctionnement des appareils auxiliaires, y compris la table tournante. Les essais ont été généralement couronnés de succès, le véhicule se montrant capable de soutenir en toute sécurité des vitesse pouvant atteindre 90 km/h. Sur le plan confort de roulement, il n'a cependant pas fait mieux que "juste satisfaisant", suivant l'échelle de confort établie par la British Rail. La durée de vie des roues et des paliers a été jugée suffisante pour les besoins du programme de démonstration. Le niveau sonore à l'intérieur, jugé trop élevé, a été ramené de 93 à 87 dB(A) par diverses modifications. Le seul problème majeur a été la panne de la table tournante qui a dû être renforcèe et modifiée après 50 cycles de fonctionnement. Les modifications visant à adapter le matériel à la circulation ferroviaire ont généralement donné les résultats attendus. Par contre, la fiabilité générale a été faible, attribuable à l'âge et aux antécédents du véhicule. Des recommandations ont été formulées dans le but de relever la fiabilité générale du véhicule.

Programme hivernal et de démonstration

Ce double programme, objet du présent rapport, a eu pour objectif l'exploitation de ce railbus sur les lignes de la INCO et du CN en vue de:

a) bâtir une expérience d'exploitation dans des conditions hivernales, dans l'anticipation d'une mise en service payant;

b) obtenir l'autorisation de la Commission canadienne des transports et l'aval du CN pour une exploitation en service payant sur la ligne Thompson-Thicket Portage-Pikwitonei du CN;

c) mettre le railbus en service expérimental non payant durant deux mois.

SOMMAIRE CONT'D

Les recommandations formulées dans le précédent rapport, en ce qui concerne les modifications à apporter au railbus, ont été réalisées, afin d'en améliorer ses performances en service hivernal. Les modifications visées ont été les suivantes: dispositif d'assistance au démarrage, utilisation de lubrifiants de qualité et grade appropriés, amélioration du filtrage du combustible et de l'air, amélioration du dispositif d'homme mort, de la table tournante et du treuil hydraulique et, enfin, relèvement du confort du conducteur.

Des essais de performances d'une durée de deux mois ont suivi, destinés à évaluer les nouvelles aptitudes du railbus dans des conditions hivernales rigoureuses. Les pannes, notamment celle de la table tournante, ont nécessité des modifications et des réparations onéreuses en temps et en argent qui ont entraîné d'importants retards sur le calendrier.

Ces réparations faites, le programme a repris sans incident pour un total de 1709 km. Tant la table tournante que les mesures d'hivérisation ont bien fonctionné jusqu'à des températures de -30°C; seule l'installation de chauffage auxiliaire s'est révélée insuffisante.

À l'issue de ce double programme, le CN et la CCT ont entrepris d'éprouver le railbus en le soumettant à des essais particuliers, dûment attestés par le CN, et portant sur les éléments suivants:

- Fonctionnement de la table tournante
- Stabilité de marche du railbus
- Confort de roulement
- Inscription dans les courbes
- Freinage
- Dispositif de l'homme mort
- Barre d'attelage
- Frein de stationnement
- Indicateur de vitesse
- Projecteurs
- Avertisseur sonore
- Feux de signalisation et de gabarit
- Équipement de secours
- Drapeaux de signalisation
- Gabarit
- Treuil de remise sur rail
- Déclenchement des signaux ferroviaires

Les essais ont débouché sur les modifications suivantes: augmentation du nombre de goupilles dans la barre d'attelage; déplacement et réétalonnage de l'indicateur de vitesse; pose d'une étiquette adhésive sur le frein de stationnement; remplacement des projecteurs par d'autres à portée plus grande; avertisseur sonore servi par un réservoir d'air comprimé séparé et caractérisé par trois notes et non plus deux; enlèvement des feux de gabarit d'origine; déplacement et repérage de l'équipement de secours; numéro matricule éclairé.

SOMMAIRE CONT'D

Avec ces modifications, le railbus a reçu l'aval pour une exploitation expérimentale sans passagers sur la ligne du CN, qu'on a voulue aussi proche que possible d'une exploitation en service payant.

Le véhicule a été pris en charge par un personnel de conduite du CN spécialement affecté, tandis qu'un observateur délégué par le contractant se trouvait à bord. Le circuit complet depuis Thompson jusqu'a à Thicket Portage et Pikwitonei prenait cinq heures. Entre le 27 avril et le 11 mai 1986, le railbus a parcouru sans incident 1903 km. Il a été établi que ce véhicule était apte à un service payant normal sur la ligne du CN qui le predrait en charge. Et, de fait, après quelques légères mises au point, il a reçu l'aval du CN et de la CCT pour transporter des passagers non payants, dans le cadre d'un programme de démonstration d'une durée déterminée.

La démonstration a été faite du 26 au 28 juin et du 26 au 30 août 1986, le railbus ayant accompli 9 cycles complets de 190 km chacun. Au bout de la première semaine, le personnel de conduite a été ramené de trois à deux personnes. L'accueil du public voyageur a été favorable et il a même fallu décourager certaines personnes par manque de place. Tout s'est donc bien passé jusqu'au 30 août, date à laquelle la roue avant gauche s'est brisée en service. Le railbus a pu s'arrêter sans encombre, et les 14 passagers ainsi que le personnel de contuite ont pu être ramenés au point de départ. Après examen de l'accident, le contractant a préconisé une réétude des roues, suivie d'autres essais. Pour sa part, Transports Canada, se rendant compte que le coût de la réétude, des essais et des modifications serait prohibitif et qu'il n'y aurait aucun avantage supplémentaire à reprendre le programme, a décidé d'y mettre un terme.

Ce programme, qui s'est déroulé sur l'équivalent de 4960 km, a mené aux conclusions suivantes, fondées sur les essais faits et l'analyse qui a suivi.

- Les modifications faites à la demande du CN et de la CCT ont relevé la maintenabilité, la fiabilité et les performances du véhicule, ainsi que le confort tant des passagers que du personnel de conduite.

- Les règles d'exploitation appliquées lors des essais du railbus sur la ligne du CN ont créé un contexte propice à la sécurité.

- La table tournante, une fois modifiée, s'est révélée fiable et sûre en service régulier. Ses performances ont été bonnes jusqu'à -40°C.

- L'installation de chauffage de secours s'est révélée insuffisante.

- La progressivité du freinage tant normal que d'urgence et des mises en vitesse a été excellente, comparativement aux autres matériels roulants, étant donné la très grande souplesse des deux commandes au pieds héritées de l'origine routière du véhicule et qui permit au conducteur de maîitriser rapidement toute tendance au patinage ou au glissement.

SOMMAIRE CONT'D

- La réétude des roues du véhicule suivie d'un programme d'essais serait indispensable si jamais il était décidé de reprendre le programme de démonstration.

- Le railbus s'est montré apte à la desserte des régions isolées dans le cadre d'un programme de démonstration de durée limitée.

- Le railbus s'est révélé comme un matérial viable et sécuritaire.

- La réglementation devrait prévoir une catégorie "railbus" dans laquelle il serait tenu compte des différences dans les exigences techniques le concernant, par rapport au matériel classique.

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1.0 INTRODUCTION

1.1 BACKGROUND

A Western Flyer bus has been converted for operation on railway tracks by Winnipeg Coach Sales and Service (WCSS) Ltd. This vehicle (Figure 1) is intended to serve as a test vehicle for evaluation of related engineering design concepts, addressing institutional and regulatory issues, and assessment of the overall feasibility of railbus operations in northern remote communities. A demonstration passenger service was planned for northern Manitoba in the winter of 1985-1986, linking Thicket Portage and Pikwitonei with the City of Thompson.

Preliminary vehicle operational tests had previously been conducted by TTL test personnel on the INCO Railway Line in Thompson, Manitoba. The results have been described in a Final Report prepared under DSS contract for the Transportation Development Centre (1).

The above report describes an exhaustive series of tests carried out over a period of three months in the Fall of 1985. The tests had the major objectives of accumulating 3,000 km of operational experience; gaining acceptance from the Canadian Transport Commission (CTC) and Canadian National Railways (CN) for non-passenger-carrying test operation on the CN line between Thompson, Thicket-Portage, and Pikwitonei; and, establishing the maximum safe operating speed on both tangent and curved track.

Plans for further operational test trials to demonstrate the vehicle's acceptance and mode of non-revenue passenger service operations were outlined in a follow-up report prepared by TTL (2). Initial tests would assess the vehicle's performance on the CN line prior to passenger service. Phase II of the plan was to operate with passengers in a non-revenue mode for eight weeks on the CN line out of Thompson, Manitoba.

The Transportation Development Centre (TDC) of Transport Canada has been closely involved with the project since its inception and contracted with WCSS for an earlier program during which the vehicle conversion to rail operation was carried out. Transport Canada subsequently purchased the railbus from WCSS.

1.2 OBJECTIVES

The Railbus Development and Demonstration Programme was undertaken by TDC under a testing agreement with the Rail Passenger Directorate (DGRP) of the Transport Canada Surface Administration.

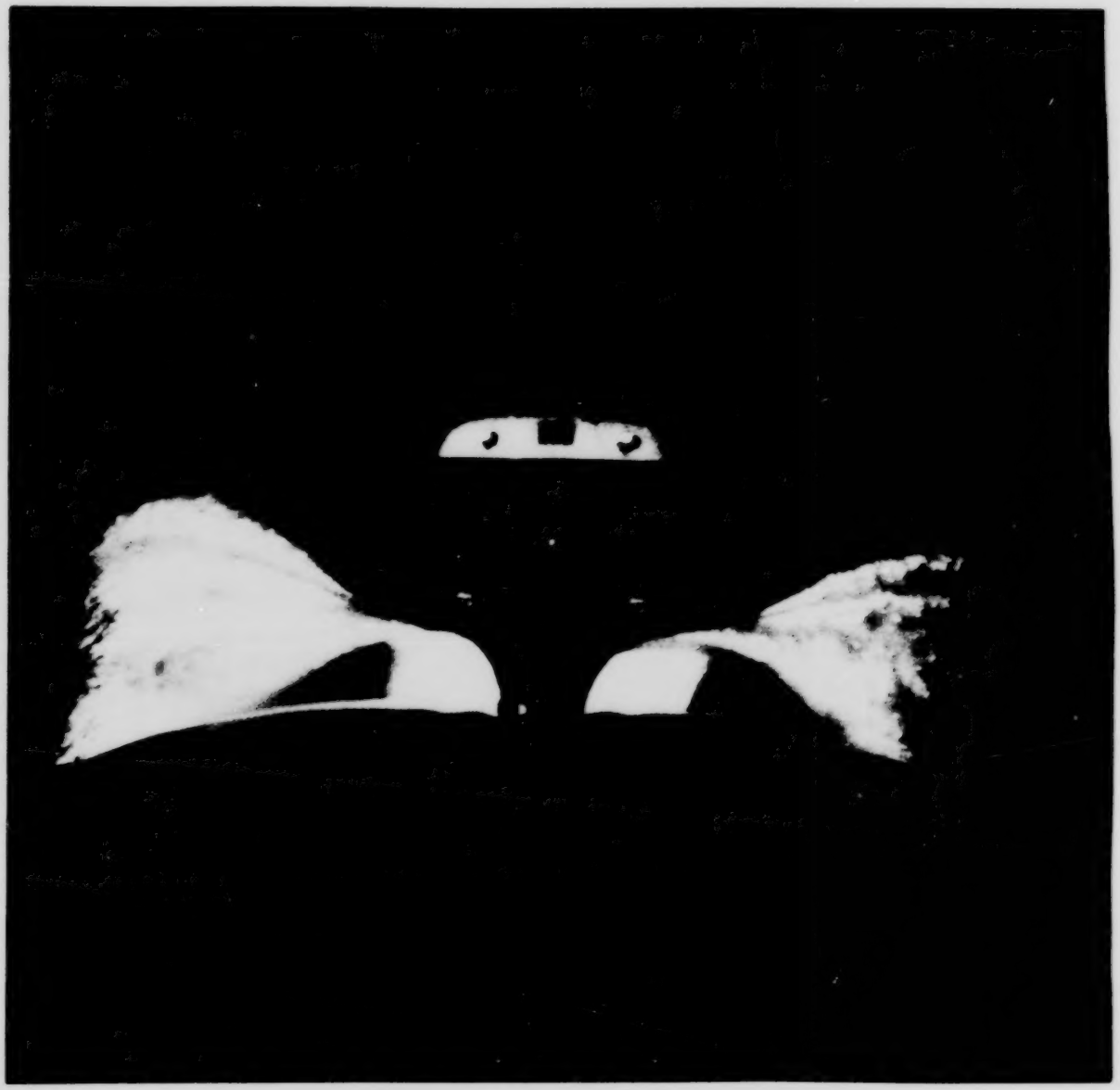


FIGURE 1 - WCSS RAILBUS - WINTER TESTING

The overall objective is to develop and demonstrate a technology suitable for rail services to remote communities where conventional rail service is extremely costly and alternative modes of transportation are not available. One element of this programme involves the testing and evaluation of the WCSS vehicle.

The specific objectives for the winter testing phase of the WCSS vehicle are to operate the Railbus on the INCO and CN Railway Lines in order to:

- o Accumulate 3,000 km of operational experience over a period of three months under winter conditions in advance of passenger operation.
- o Gain acceptance by CN Rail and by the CTC for operation in passenger carrying service on the CN Thompson-Pikwitonei-Thicket Portage Line.
- o Operate the Railbus over a period of eight weeks on the CN line in a non-revenue passenger demonstration service.

1.3 METHODOLOGY

The methodology followed for the work consisted of a logical sequence outlined below:

- o Engineering assessment
- o Vehicle improvements and preparation
- o Vehicle winter test on INCO Line
- o Vehicle modifications
- o CN and CTC acceptance
- o Vehicle non-passenger test on CN Line
- o Vehicle passenger test on CN Line.

Prior to the engineering and test activities, documentation for an application to the CTC for permission to operate on the specified Thompson-Thicket Portage-Pikwitonei railway line was prepared and submitted to TDC.

The vehicle preparation was largely carried out at a local machine shop in Thompson using machine shop and TTL engineering personnel. A photographic record of the vehicle and testing is included in this report as Appendix A-1. An engineering assessment consisting of an analysis and performance review of such parameters as turntable reliability as well as a comparison of the vehicle status with the known requirements of the CN and CTC was also carried out.

Vehicle improvements were carried out to rectify known deficiencies from previous testing, incorporate changes suggested by the engineering assessment, and carry out specific vehicle changes required by the CN and CTC. This work was followed by intensive vehicle winter testing on the INCO railway line including trials of cold weather durability. Preliminary tests, particularly those of the turntable and engine resulted in the requirement for further vehicle modifications prior to commencement of the CN Line tests. All the vehicle modifications were carried out while in Thompson. The program concluded with the non-revenue passenger service demonstration and analysis of the test results recorded.

1.4 ORGANIZATION OF THE REPORT

The organization of the report follows the above outlined methodology closely. Section 2.0 reviews the vehicle's assessment and the operation preparational work required to carry out the program. Winter tests conducted on the INCO line are described in Section 3.0. Following the vehicle modifications to meet CN and CTC acceptance as outlined in Section 5.0, the Railbus was tested on the CN line. The results of the non-passenger test portion of the program are summarized in Section 5.0. The final phase of the test program assessing the comments acceptance in view of non-revenue passengers is reported in Section 6.0. This section also addresses the failure of the wheel design which led to the termination of the test program.

Section 7.0 of the report summarizes the conclusions of the work and the formulated recommendations of the work carried out.

2.0 VEHICLE PREPARATION FOR WINTER TESTING

2.1 RECOMMENDATIONS FROM PREVIOUS TESTING

Review of the preliminary service demonstration conducted in the Fall of 1985 on the INCO line had led to the following recommendations for vehicle improvements prior to the start of the winter test program:

- o The turntable hydraulic system to be reviewed and reworked to provide an equal lift/lowering capability under all load conditions and temperatures;
- o The hydraulic fluid to be replaced from a low-temperature type to an arctic-type;
- o The hydraulic winch to be modified to provide the required rotational rate;
- o The driver instrumentation panel to be updated with improved/ additional monitoring gauges, and a calibrated speedometer;
- o Assess and improve engine startability and emergency shut-off;
- o The fuel supply to have a water separator and fuel heater installed near the tank;
- o The air supply to have an air-drier installed to remove moisture, oils and residues;
- o The design and operation of the emergency heater to be reviewed and its specified thermal output verified;
- o Driver comforts to be added including an arm-rest, privacy screen, dash mounted grab-bar and a glare free paint finish over the windshield area;
- o The operation of the deadman switch to be modified to prevent the operator from over-riding its action; and
- o Further trials be carried out in full winter conditions before passengers are carried, in order to eliminate any remaining problems not discovered during less severe Fall weather conditions.

2.2 INITIAL VEHICLE PREPARATION

In view of the potential severity of weather conditions which could affect the performance of mechanical and electrical equipment operating out-of-doors, various features and improvements were added to the WCSS railbus. Vehicle inspection and rework commenced during the weeks that followed the start of the test program on 17 December 1985. Wheel surfaces, wheel mounting faces and vehicle structural components were inspected, and equipment modified to assist in the reliable operation of the vehicle while in hostile winter conditions.

The following section summarizes the changes made to the Railbus prior to the mileage accumulation exercise (3000 km) initially to be carried out on the INCO Railway. The work was mostly completed within the Mutschel Bros. Machine Shop (Thompson), during the months of December 1985 to February 1986. (3, 4)

2.2.1 Fuel System

The fuel supply and filtration system were modified to include several features designed to ensure an adequate fuel delivery to the engine. Work carried out included:

- Fuel Heater - electrically operated (375 watt) which included an auxiliary in-line engine coolant heat exchanger was installed;
- Fuel Water Separator - clear glass-bowl design which included a high-capacity fuel filtering system was installed; and
- Fuel - tank was drained and fuel replaced with an arctic grade (P50) having superior anti-wax specifications.

2.2.2 Air System

A water separator was added to the air circuit and located within the front left side luggage compartment.

2.2.3 Hydraulic System

The hydraulic fluid was drained and replaced with a low-temperature winter grade (Esso N-Artic) suitable for operations to -46°C (25 litres).

2.2.4 Rerailing Winch

The hydraulic pump and motor were replaced with better matched designs enabling the power winch to operate at a faster speed. Replacement of the pump from 6 to 13 GPM and motor displacement from 24 in^3 to 10 in^3 gave an acceptable speed performance of 6 RPM (no-load) to the winch operation.

2.2.5 Snow-Plow Pilot

Two spring-loaded rail scrubbers designed in a previous program by WCSS were mounted to the underside of the pilot, forward of the front wheels. In addition, the pilot height was adjusted to give a clearance of 100 mm (4.0 in) between the lower edge of the pilot and surface of the rails.

2.2.6 Wheel Sanders

Sand containers, electric solenoid operated valves and controls were installed in front of the rear axle.

2.2.7 Engine

A manually controlled pull-cable was installed to shut off the engine power in the event of an emergency.

The engine oil was drained and replaced with a winter grade (Texaco HD 15W40). The oil filter was also replaced.

To assist in the starting of the engine when the vehicle is kept out-of-doors, the following winter aids were installed on the engine:

- Oil pan heater (90 Watts); and
- Ether injection system to air inlet manifold.

In addition the Engine coolant heater was debugged and tested.

2.2.8 Battery

An auxiliary bus battery was added to the electrical system, with necessary controls adapted to charge and isolate the units in operation.

The emergency power shut-off switch's operation was reversed so that the +'ve side of the battery is disconnected from the electrical circuit.

To help in maintaining peak engine cranking ability for cold weather start-ups, a battery trickle charger was connected to the primary battery, to use wayside power at 110 V overnight.

2.2.9 Headlights

The front-mounted vehicle headlights were replaced with two 100-watt H4-Halogen lamps (Bosch) designed for directional lighting. Two pilot-mounted spot lamps (60 watts each) were also installed to provide the additional lighting required by CTC Order O-14 to obtain 262 m (800 ft) of illumination.

2.2.10 Dead-Man Control

The operation of the dead-man control circuit was improved by increasing the air solenoid operating pressure from 40 to 60 psi and modifying mechanical advantage of the activation levers. Tests have demonstrated that the additional mechanical effort obtained from the alterations provided a satisfactory return to idle for the engine throttle control, when the dead-man foot-activated switch was released.

2.2.11 Cab and Controls

Features added to the driver control area included:

- Elbow rest - added to the left side cab wall;
- Fuel gauge - replaced;
- Voltmeter;
- Non-glare Paint - over the visor of the front windshield;
- Privacy Curtain - behind the drivers' head;
- Grab-Handle - insulated; and
- Control Switches - fuel heater
  - wheel sanders
  - engine shut-off
  - auxiliary headlights

Maintenance items, as well as control switches were clearly identified and marked at various places on the vehicle.

2.2.12 Emergency Heater

The fuel-line size was increased to 6 mm ($\frac{1}{4}$ in) to improve the fuel delivery rate to the emergency burner unit. The assembly appeared to operate satisfactorily within the machine shop after the modification.

2.2.13 Hydraulic Turntable

To improve the controlled rate of fluid flow to the 4 hydraulic lift/lower cylinders, the 3 existing flow dividers were replaced with 8 temperature-pressure flow compensator control valves. The re-design and installation was intended to control within ±3%, the fluid-flow out of the hydraulic cylinders during vehicle lift and lowering procedures. The valves were mounted on manifolds located within the front right side luggage area. The design permitted simple adjustments and proper sequencing of the system while observations could be made of pressure gauges located on the manifolds.

Hydraulic modifications to the turntable control system included the replacement of the main relief valve since the seals were found to be damaged and adapting 2 adjustable pressure-relief valves to the turntable lift/lower control section.

The hydraulic cylinders were inspected and rebuilt as a result of the discovery of oil leakage, fractured rod-ends, and the poor internal cylinder seal design used at the piston interface.

The assembly of the turntable structure was inspected and concluded to be poorly fabricated. Fatigue cracks, as well as severely bent major components were discovered and concluded to have caused the difficulties previously reported when operating the system. In the re-design, the hydraulic lift cylinders were modified by bolting the assemblies to the turntable (rather than screwed onto) with cushion mounts used to assist in their proper alignment. The internal guides and support plates were also replaced and reinforced with stiffer channels added to the upper guide assembly.

Details of the modifications made to the hydraulic turntable system are shown in Figure 2.

2.3 EMERGENCY EQUIPMENT

In addition to the vehicle improvement for winter operation as outlined in the previous section, the railbus was fitted with various safety and emergency supplies designed to help in winter or emergency operation of the vehicle. Such supplies included:

- first aid kit (large size);
- stretcher;
- supply of blankets (4);
- snow-suits (2);
- mobile telephone installed by Manitoba telephone system;
- CN two-way radio;
- flagging kit; and
- flares.

In addition, emergency equipment stored on-board included:

- portable rerailing guide plates (2);
- portable tow and drawbar attachment suitable for either end of the railbus (See Figure 3);
- length of towing chain or cable;
- switch broom;
- sledge hammer;
- shovel;
- axe;
- saw;
- fire extinguisher; and
- portable jack.

If a derailment, fire, crash or any form of tragedy occurs, once the passengers' welfare has been provided for, contact with the train dispatcher will be made immediately using one or the two onboard radios.

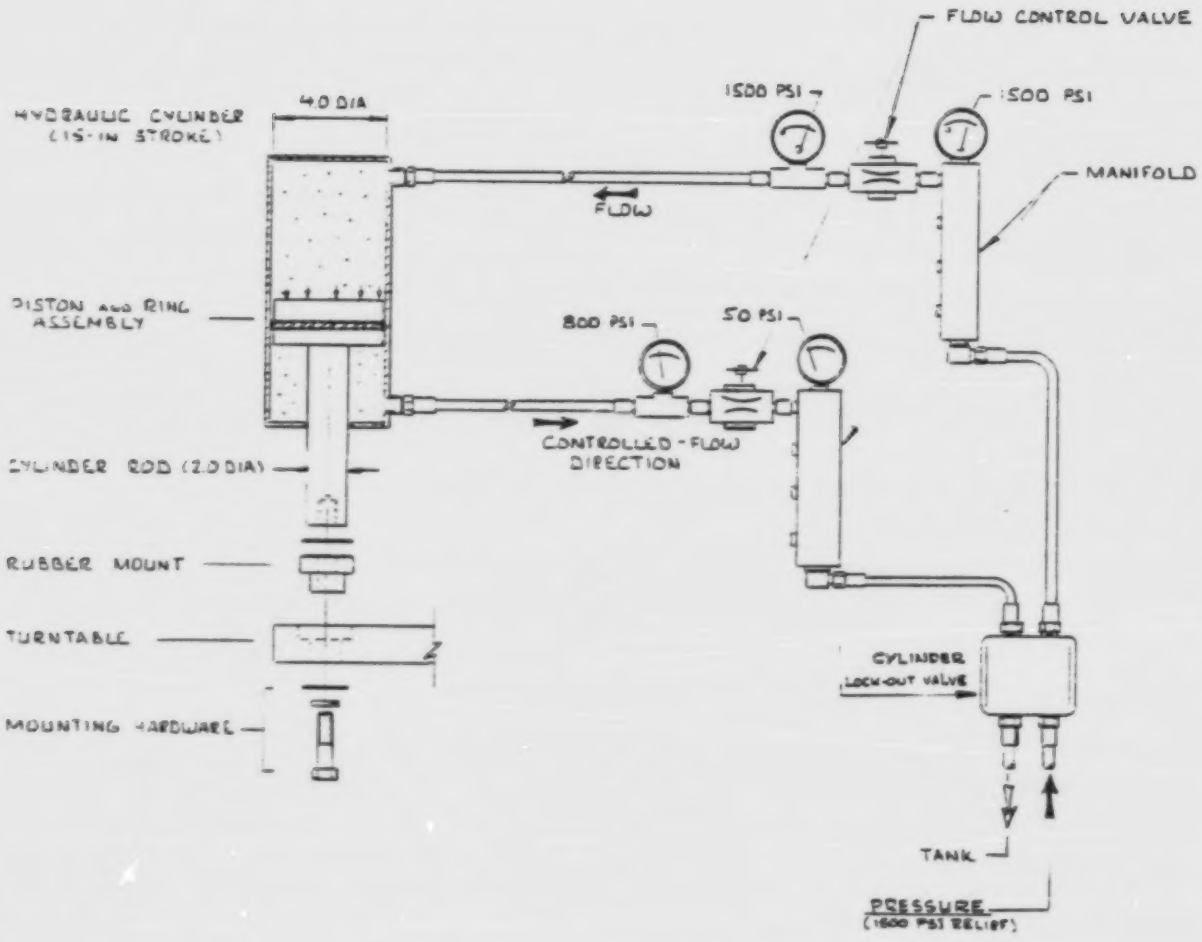
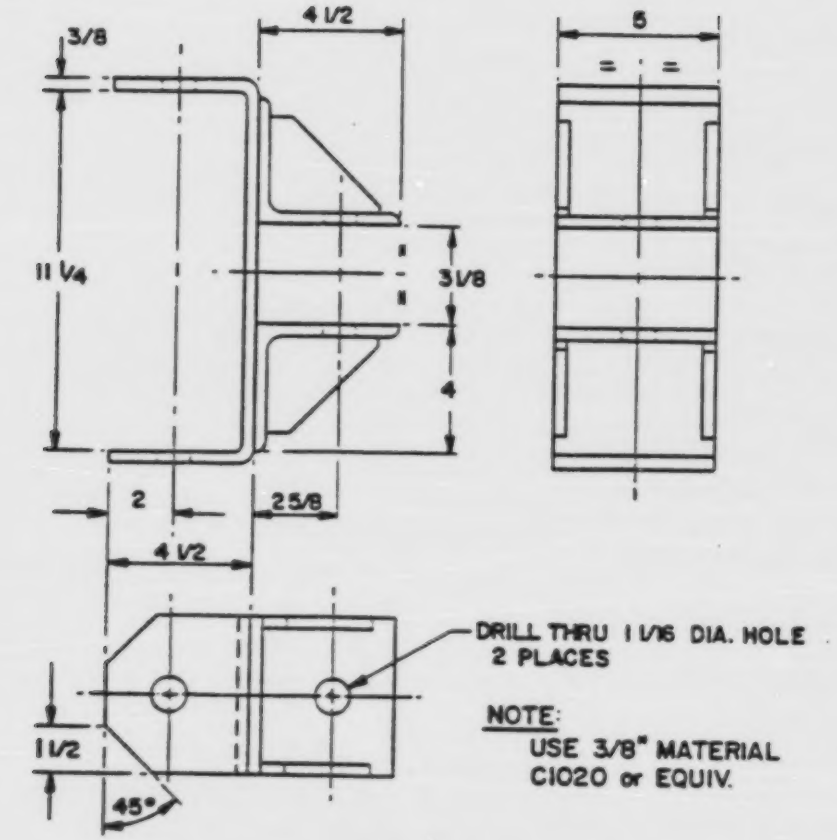


FIGURE 2: DETAIL OF HYDRAULIC CONTROL CIRCUIT AND CYLINDER DESIGN - MOUNTING

TOW-BAR HITCH:



NOTE:
USE 3/8" MATERIAL
C1020 or EQUIV.

TOW-BAR EXTENSION:

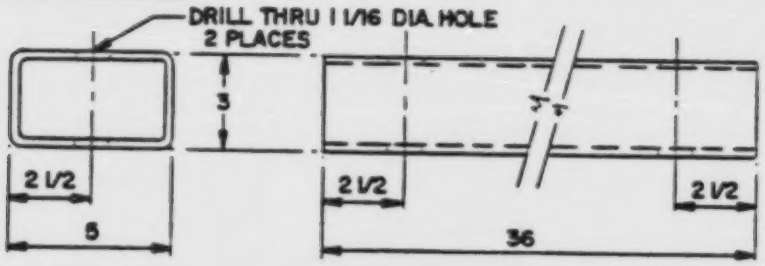


FIGURE 3: DETAIL OF LIGHT-WEIGHT TOWBAR DESIGN

The train dispatcher will assess the situation from an operational standpoint and make arrangements for medical assistance, helicopters, advance notice to local hospitals and, if necessary, the auxiliary train.

2.4 TRACK FACILITIES

During the first phase of the winter test program, TTL would require access to INCO's 40 km section of track between Thompson and Pipe Lake. Arrangements were made with Mr. M. Babulic, Superintendent of Transportation, for access to the track and emergency use of maintenance facilities. On-site personnel were instructed on current rail operations in consideration of the winter conditions to be encountered.

With production terminated at Pipe Lake mine, the track between Thompson and the mine was available to TTL personnel for testing without interruption. A positive operating procedure was set with INCO's transportation office to use the track on a daily basis. In the event of a derailment or heavy snow fall accumulations which would prevent further testing of the railbus, emergency assistance arrangements were set-up with the Maintenance Track Supervisor.

Third party access to INCO facilities was arranged with TTL coordinating their movements and the on-site supervision.

2.5 REPAIR FACILITIES

The severity of cold winter temperatures on the startability of mobile equipment generally necessitated INCO to accommodate most of their own locomotives indoors at nights. This resulted in limited access and time availability to complete the repairs necessary for the continued testing operation of the Railbus. Alternate vehicle storage and repair facilities were arranged for locally through the assistance of the Mutschel Bros, Machine Shop, Thompson.

To transport the Railbus between the test track facilities and Machine Shop required the Railbus to be towed on its road wheels. Towing distance was approximately 2 km to the nearest level crossing where the Railbus' turntable was used to lift and relocate the bus back over the rail tracks surface.

2.6 DRIVERS AND TRAINING INSTRUCTIONS

As the TTL employees had become sufficiently proficient with the operation of the Railbus, INCO agreed that TTL could continue to operate the vehicle, while on INCO property, under the control of the test employees present. An additional mechanic/driver was employed by TTL from Mutschel Bros. during the duration of first phase portion of the program.

Prior to operating on the mainline, arrangements were made for advance introductory training of the CN crew which would be employed by TTL during the subsequent series of tests on the CN line. This training was carried out on the INCO line.

2.7 LIABILITY AND VEHICLE INSURANCE

Personnel, liability and vehicle insurance for testing on the INCO line was arranged with Thomenson Inc. between INCO Manitoba Division, CN Rail, and TTL, with the insurer being "Commonwealth Insurance Company" Policy No. CRX5020. For operation on the CN Line insurance was arranged with the Facilities group of the Ontario Government.

2.8 CTC APPLICATION

Based on the results of a review meeting held with TDC, CN and CTC at Thompson, Manitoba, September 2 1985, it was recommended that the application to the CTC for non-passenger operation be submitted jointly by CN and TDC. TDC submitted an advance application while the appropriate approvals were obtained within CN. This advance application included the data submitted on 10 October 1985 (Ref. 11). It was concluded by the CTC that the application must be received directly from the operating railroad (CN) before any CTC authorization could be issued. CN's formal submission to the CTC for non-passenger operation on the Thompson-Thicket Portage-Pikwitonei route was submitted January 17, 1986 and CTC's authorization to allow operation without passengers was issued on 28 January, 1986 under Order No. R-38999. The specific operational agreements with CN had been carried out with the assistance of CANAC.

3.0 INITIAL VEHICLE TESTS - INCO LINE

3.1 GENERAL DESCRIPTION OF TEST PROGRAM

The vehicle was tested during February and March 1986 on the INCO Railway Line. Test observations and data recorded followed procedures outlined in the test plan (5). Results from the tests are summarized in this section.

Several specific tests were performed during the first phase of the program to evaluate the vehicle's winter reliability and acceptability for operation prior to its service demonstration on the CN Line.

The following sections outline the vehicle features required for evaluation. The test approach focused primarily on two major areas under review:

1) Design Improvements

   - Tests to be conducted to evaluate recent vehicle design improvements and additions in order to assess their reliability and suitability during operations in winter conditions.

2) CN and CTC Requirements

   - Tests to be conducted to evaluate recommended vehicle modifications incorporated into the design in view of CN and CTC technical and operational requirements.

The major portion of the test program was scheduled to be completed during the winter months of January and February, 1986, but was delayed as a result of the failure to the turntable described in Section 2.2.13. The vehicle would be in its unladed configuration (10310 kg). An outline of the tests completed during the first phase of the winter test program is given in Table 1.

3.2 SUMMARY OF RESULTS

The WCSS Railbus was tested as described during the winter months on the INCO rail line. Following the tests, the vehicle's operation was to be assessed by CN officials and recommendations to be made on the concepts' suitability for a continued non-passenger service demonstration. A summary of observations made on the design and operation of the Railbus prior to CN's assessment are as follows: (6)

Major Area of Review	Test Description
Design Improvements	o To assess reliability of the turntable and hydraulic control system. o To assess the operation of the rerailing winch. o To assess the suitability of the emergency heater. o To verify the operation of the emergency engine shut-off switch. o To assess engine startability and starting aids when operating out-of-doors. o To assess the operation of the pilot and traction ability during track clearing operations.
CN and CTC Requirements	o To evaluate reliability and wear tendencies under the impact of winter conditions. o To evaluate ride quality and stability while operating on snow bound tracks. o To verify the attachment and safe operation of the light-weight draw-bar attachment. o To assess the performance and reliability of starting and stopping the vehicle during emergency operations in winter conditions. o To verify the suitability of the vehicle markers, classification, and headlights for operation on the CN Line. o To evaluate vehicle performance over railway crossings. o To assess vehicle maintenance requirements prior to passenger service. o To develop operating procedures in the event of a mechanical failure or derailment.

TABLE 1: SUMMARY OF INCO WINTER TESTS

Turntable System - The modified hydraulic system and vehicle support structures operated satisfactorily during the 66 vehicle lifts completed. Problems reported prior to the tests (i.e., unequal lift, high working pressures, fatigue cracks) were found to be non-existant to-date. The operation and reliability of the hydraulic cylinders and control system were judged as acceptable for continued use with the vehicle.

Rerailing Winch - The hydraulically operated power winch was tested and determined to have sufficient power and pulling rate to tow the vehicle during a re-railment exercise. The modified track plates ('Butterflies') and rail ramps were used to assist in the rerailing exercises.

Emergency Heater - The auxiliary emergency heater was found to be intermittent in its operation and could not be reliably activated (due to electrical problems). The system was unreliable and not recommended for use in an emergency service application.

Emergency Engine Shut-Off - The addition of the manually activated pull-cable to disable the engine in an emergency, operated satisfactorily during the test trials. Improvements made to the air solenoid circuit and method for the activation of the dead-man control system operated satisfactorily during tests conducted at various vehicle speeds.

Engine Startability and Reliability - The performance and reliability of the engine starting aids were tested and found to be acceptable depending upon the severity of the ambient temperature. The coolant heater, recirculator and oil pan heater operated satisfactorily but only when temperatures were above -30° C.

Necessary additions to assist the start-up of the vehicle when cold-soaked were due to viscosity changes in the engine oil, the larger engine starter, the ether inject system, and the battery trickle charger. The failure and replacement(s) of the original engine starter and fuel injector nozzle resulted in several delays to the test program. Eventually a larger starter motor was installed.

Snow Removal and Winter Protection - The snow plow pilot had performed satisfactorily in clearing the tracks of snow accumulation (up to 250 mm). Engine power was adequate to permit rail speeds to 60 km/h; wheel sanders were required in some situations.

Snow and ice accumulations on the turn-table and undercarriage appeared to have little if any detrimental affect on the operation of the system. Shields were not installed around the turntable.

The brake drums and control linkages had become inoperative due to ice build-up during the tests resulted in the addition of an air-activated 'snow-brake' feature to keep the service brakes clear and operative. Shields around the brake drums were not installed.

The engine area partially packed with snow, caused minor engine control problems. A canvas engine under-shield was later installed and provided limited protection.

Rail-scrubbers mounted to the underside of the pilot were of no benefit during the winter tests and were removed.

Reliability and Wear - During the winter test trails, the Railbus had accumulated nearly 1,600 km (990 miles) of operational track experience. Inspection of wheel surfaces, bearing play, turntable and structural components indicated the equipment to be in satisfactory condition.

Draw-Bar Operation - The assembly and application of the light-weight draw-bar attachment was tested and shown to be of an acceptable design for use during an emergency vehicle recovery.

Traction and Braking - The wheel sanders operated satisfactorily in providing assistance for the necessary traction ability of the Railbus. The design of the standard bus differential and rear-axle drive assembly proved to be an acceptable arrangement for use on the vehicle. The sanders were not generally required for use during service and emergency brake applications.

Vehicle braking distances were tested and found to be acceptable following the application of the 'snow-brake' feature.

Lighting - The installation of the marker and classification lamps added to the front and rear of the Railbus were judged as being acceptable by CN officials. The operation of the lights was later verified.

The initial illumination range (182 m) of the main headlights was not acceptable for use on CN tracks if the vehicle was to be operated in evening service. The headlights would require to be improved to meet CTC order O-14.

Railway Crossings - The tests demonstrated the vehicle could generally travel over snow and ice packed railway crossings. Occasionally in extreme icing conditions it was found to be necessary to check and clear ice by hand to ensure adequate rail/flange guidance.

Total miles accumulated during the initial winter tests conducted on INCO's Rail Line amounted to 1068 miles (1709 km).

4.0 VEHICLE MODIFICATIONS FOR CN AND CTC REQUIREMENTS

4.1 REVIEW OF CN AND CTC REQUIREMENTS

It was concluded during the planning stage of the program that a formal application would be made to the CTC detailing the approach to be taken to satisfy the requirements. This application would be in two distinct stages, the first for non-passenger operation and the second for non-revenue passenger carrying operation. These applications would request exemption in certain specific areas namely:

- bell;
- sill steps;
- ladders;
- running boards;
- sparks arresting system;
- hand holds; and
- coupling device.

The vehicle is equipped with a driver-activated drop-down step for passenger convenience and safety. Other items mentioned in the previous paragraph are considered inapplicable for this specific application.

Additional requests were made by the CNR for:

- protective barrier for the operator;
- daily inspection and maintenance of the vehicle; and
- modifications to support the vehicle weight for rerailing purposes in the event of a derailment.

These requests were further considered and implemented, prior to operation on CN Rail's Thompson Line.

In consideration of the CN operation area, and the absence of centralized traffic control, crossing protection signals and public crossings at grade, relief on the items indicated above was recommended by TTL.

4.2 REQUEST FOR VEHICLE TEST

Preliminary vehicle modifications had been carried out on the design of the Railbus, primarily to improve the vehicle's reliability for winter testing. Equipment additions had also been made in accordance with previous CN requests in order to meet the requirements as stated by various CTC rules and regulations.

CN technical and operations officials were requested by TTL Engineering to inspect and review the updated WCSS Railbus design in order to gain acceptance for further testing on the CN Line. Test trials were scheduled to be conducted while on the INCO track

in Thompson, Manitoba. Daylight and evening operational tests were performed on 10 and 11 of March 1986.

4.3 CN ASSESSMENT

In general, the CN observers expressed favourable acceptance of the improvements made to the design of the Railbus. Very little trouble was encountered during the test trials. Curving, stability, ride quality and vehicle behaviour was considered to be acceptable while operating in the cold winter conditions encountered. A summary of tests conducted and observations made on the performance of the vehicle are as follows:

4.3.1 Turntable

The turntable and hydraulic control system was cycled several times (4) and successfully turned the railbus without incident or difficulty. CN expressed interest in and satisfaction with the units operation.

4.3.2 Vehicle Stability

The railbus was operated at rail speeds of 70 km/hr on tangent track where snow could be plowed (75-100 mm). The vehicle performed satisfactorily and wheel/rail stability was acceptable. Engine power was adequate for the speed and poor rail conditions observed.

4.3.3 Ride Quality

The ride quality was described by CN as being better than anticipated considering the poor track conditions and crude suspension system. Interior noise level was a little high but acceptable for further operations on CN tracks.

4.3.4 Curving

The vehicle was driven at speeds of 8, 16, and 24 km/h through INCO's tightest curve (10°). Reverse speed up to 16 km/h was also performed through the same curve. The ride in the curve was acceptable and minor wheel-squeal was evident. The axle/wheel motion was stable and the previously recorded comment made of the vehicle "Crabbing" through the curve during tests of the unmodified vehicle was not evident in the test. (Note that the rear axle differential was unlocked when rebuilt in November 1985). The suspension was commented upon as being satisfactory for the vehicles application.

4.3.5 Braking

Initially when the service brakes were operated, the vehicle failed to stop in the required distance. Upon activation of the

snow-brake system and running the vehicle for nearly 1 mile, the brakes were again tested and stopped the vehicle in the required distance and time (16 seconds from 48 km/h). The operation and application of the brake system was said to be satisfactory.

4.3.6 Deadman Control

Following the readjustment of the deadman brake line pressure to 40 psi, the control system operated satisfactorily and stopped the vehicle from 48 km/h in the previously quoted time of 16 sec.

4.3.7 Towbar

The recently redesigned lightweight towbar was installed between the rear of the railbus and head-end of an INCO yard locomotive. The vehicle was successfully pushed and towed through the 10° curve to the satisfaction of the CN observers. The 1-inch diameter bolts (3) used to secure the towbar to the vehicles were to be modified to incorporate safety-pins to prevent their loss during use.

4.3.8 Parking Brake

The application and operation of the manual park-brake was adequate (stopping the vehicle from 32 km/h), however, CN requested that TTL apply a warning decal to the control console which would read: "Apply park-brake when leaving vehicle". Their concern was that with the air-brake system employed, loss of air pressure may result in brake release and the vehicle moving if unattended.

4.3.9 Speedometer

CN indicated they would prefer to see the speed indicator accurately adjusted and made easier to view by the operator.

4.3.10 Headlights

The railbus was tested at night to observe the forward illumination range of the headlights. The current configuration was sufficient to allow the operator to view a man standing on the track at a distance of 182 m (600 feet). However, CN requested additional lighting be installed in order to satisfy the CTC requirement for 243 m (800 ft) illumination range. Alternately, CN suggested the vehicle not run during night operations.

4.3.11 Horn

The two-tone horn was judged to be acceptable in its sound level, however, since the CTC regulations state a three-tone unit be used, we were asked to comply with the ruling.

4.3.12 Classification and Marker Lights

The marker and classification lamp locations were judged to be acceptable, front and rear, however, upon test the rear marker lights did not function. A blown fuse was traced to be the problem and spare bulbs and fuses were requested to be stored on the vehicle. CN requested all other rear and forward clearance and signalling lamps be disconnected in order to avoid confusion with other trains operating on the same rail line.

4.3.13 Safety

CN requested to see the flag kit and location of the emergency tools and supplies. All were present however, it was observed the tools and emergency supplies were "scattered" throughout the vehicle and difficult to locate. It was suggested that further work be done by field personnel to properly and securely locate the equipment.

4.3.14 Flags

CN requested white flags be mounted to the front of the railbus. In addition, green lights and flags were requested to be mounted on the front, however this was later determined to not be required for the territory being serviced, since the railbus would always be operating as an 'extra' train. (Confirmed by CN.)

4.3.15 Clearance

The addition of the emergency lifting tube (4" x 4") to the rear of the vehicle made the railbus exceed the plate 'C' clearance profile. However, since the railbus is also classed as a locomotive, the profile is larger and acceptable for the railbus design. The pilot height was measured to be at an acceptable height (4-inch above railhead).

4.3.16 Train Number Light

CN requested a suitable identification light be added to the front of the vehicle.

4.3.17 Emergency Heater

The emergency heater was not requested to be tested, however, it was indicated by TTL that an alternate portable unit would be carried on the vehicle for emergency use. The heater would also be used to warm the engine to aid in starting in the event of a power failure when operating on the CN line.

4.3.18 Rerailing Winch

The rear-mounted winch and guide ramps were inspected by CN and it was expressed that they were suitable. Although a rerailing operation was not tested with CN present, they were satisfied with an explanation of how the equipment had been successfully employed on two previous occasions.

4.3.19 Signal Test

The railbus was used to demonstrate the successful activation of the road crossing signal located within the INCO maintenance yard. Considering that no other railway crossing signal is located on the demonstration line to be serviced, CN indicated their satisfaction with the vehicles overall performance.

4.4 SUMMARY OF RESULTS

The tests observed by CN officials (7) indicated the following items were required to be added or resolved in the design of the WCSS Railbus:

1) Towbar - add safety pins;
2) Park-brake - add decal;
3) Speedometer - relocate and calibrate unit;
4) Headlights - increase illumination or not operate vehicle at night;
5) Horn - add third 'trumpet';
6) Marker Lamps - remove rear-end clearance lights and place on-board spare parts (lamps, fuses);
7) Safety - clearly identify and locate for easy access to emergency equipment;
8) Flags - add white flags to front of vehicle
   - resolve issue of adding additional green lights and flags to front of vehicle; and
9) Train Number - add appropriate lighted identification unit.

Following the additions and modifications to the vehicle as requested and the verification of their application, CN indicated they would accept the WCSS Railbus design. In its final configuration CN concluded that it would also satisfy, to the best of their knowledge, the requirements as set out in the CTC regulations.

4.5 FINAL VEHICLE CONFIGURATION

As requested by CN officials, the WCSS Railbus was further modified into its final operational configuration. The protective barrier for the driver earlier requested by CN was replaced by a roll-up type privacy screen. Items identified and added to the concept's design are summarized as follows:

Safety Pins - Proper safety pins were installed onto the drawbar attachment bolts located within the luggage compartment.

Speedometer - The unit was removed, recalibrated and mounted in an inclined position for easier viewing. Vehicle speed was verified during subsequent tests.

Headlights - Two additional Bosch high intensity spot-lights were installed onto the pilot. Further tests indicated illumination was adequate to observe a man standing on the track at a distance of 800 ft.

Horn - A CN specified three-tone horn was installed to the front of the Railbus. The air system was modified to incorporate additional air reservoir capacity to compensate for the high air useage of the CN locomotive horn. In addition check valves were installed to preserve integrity of the air brake system when the horn was operated.

Classification and Marker Lights, Flags - All vehicle lights were corrected for proper operation as requested and white flags installed on front of the bus.

Safety - Emergency tools and equipment were relocated for easy access and identification. Decals were added to various switches and control devices to aid in proper identification.

Train Number Light - A lighted number box was fabricated and installed onto the forward section of the roof. The vehicle was identified as "WCSS-1".

In addition to the modifications requested by CN, several recommended improvements suggested by a TTL engineering assessment of the winter tests at INCO were also incorporated. These on-going modifications as reported in various TTL field reports were intended to primarily improve the ignition and engine starting operation and gain reliability in the turntable and drive-train assembly. Telescopic beams and items to be used for lifting the bus in the event of a derailment, were sent to CN's salvage depot.

Following the repair work, the WCSS Railbus was cleaned and serviced as per the recommended maintenance procedures developed, and engineering and test personnel made ready for the continuation of testing on the CN Rail Line.

5.0 VEHICLE OPERATION AND ASSESSMENT ON CN LINE - NON-PASSENGER SERVICE

5.1 GENERAL DESCRIPTION OF TEST PROGRAM

The overall purpose of the railbus test program is to verify operation of safe, reliable, new form of transportation which can be placed into operational passenger service for remote communities. In order to achieve this overall goal a logical progression from operational requirements through design, test and demonstration is required. In parallel with, and interacting with, the hardware development activities there is the equally important requirement to develop the software, i.e., operational strategies, required to operate this new vehicle in a safe manner in a real environment rather than a test track. (8)

The objectives in the first non-passenger stage would be to:

- Demonstrate Railbus operation in a real railway environment;
- Develop and test operating procedures;
- Train personnel in railbus operation; and
- Uncover and rectify vehicle and operational deficiencies.

In the second stage the objective would be to:

- Carry out preliminary passenger carrying trials in a non-revenue generating manner in order to determine user reaction to the service.

The location of the demonstration test service was between Thompson, Manitoba and two outlying communities, namely Thicket Portage and Pikwitonei. This area is shown in Figure 4. The service was centred in Thompson and travel to Thicket, then to Pikwitonei and return to Thompson. The two outlying communities each have a population of approximately 200 and Thompson itself acts as a commercial hub for the whole region with a population of nearly 15,000.

In the initial plan, the railbus would not operate when a CN or VIA regular train is on any of the Thompson "T" Service area. The Railbus was therefore scheduled so that a total round trip could be made either before or after the regular CN/VIA Service had entered or cleared the service route.

Considering an average rail speed of 50 km/h is observed for the WCSS Railbus, it has been established that 1 round-trip would take no longer than 5 hours (using current published passenger train time-table speeds). In the estimate, a 0.5 hour stop-over at each of Thicket and Pikwitonei were considered.

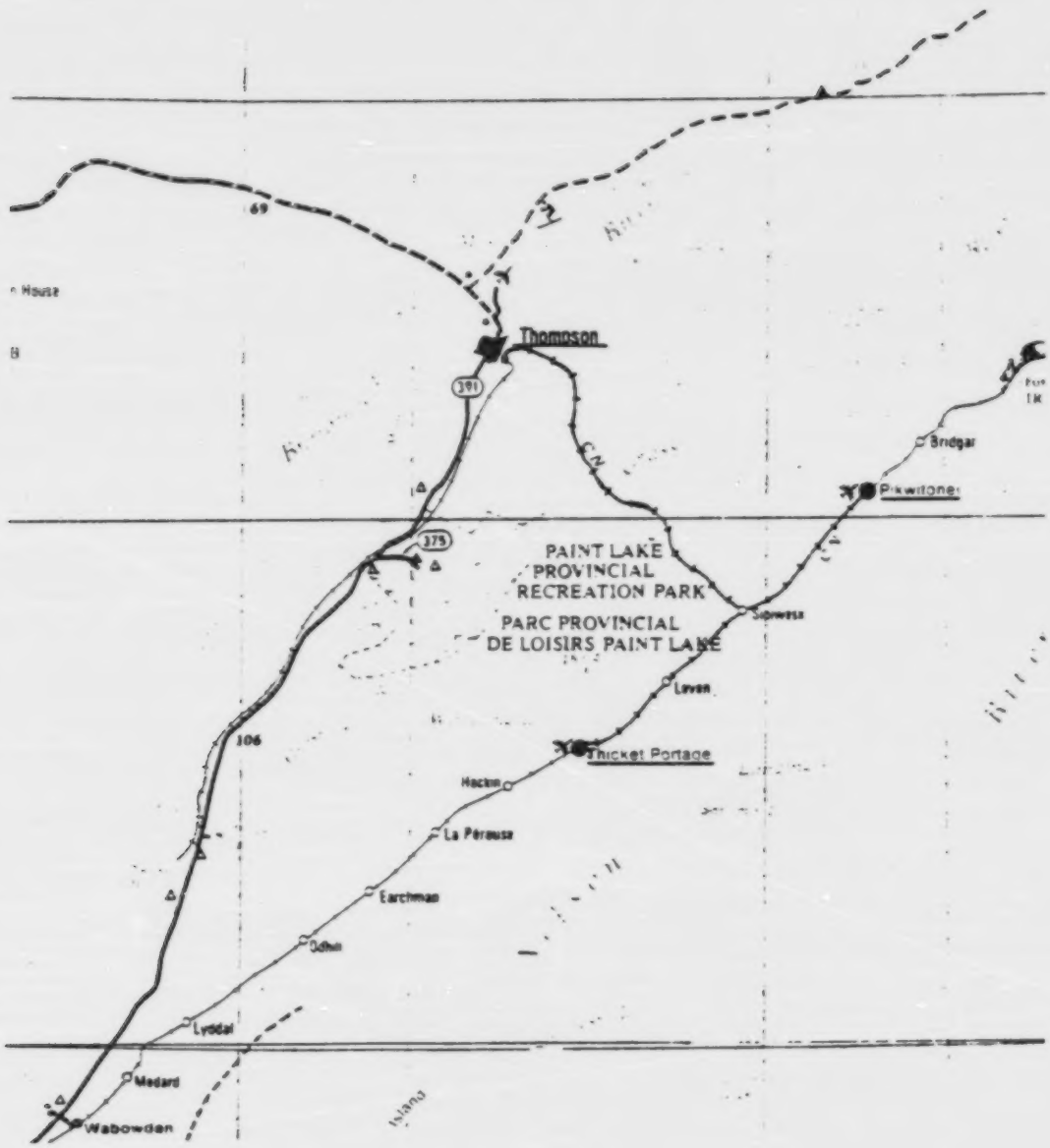


FIGURE 4: RAILBUS SERVICE LOCATION

In view of the track occupancy times by other trains (Passenger and Freight) on the serviced route and in consideration of the maximum time required for a round-trip, it was possible for the Railbus to operate during normal hours in the following mode:

- Two (2) round-trips on Tuesday, Thursday and Saturday; and
- One (1) round-trip one Sunday and Monday.

It was originally envisaged that initially there would be a two-man crew consisting of a CN trained engineman and conductor. It was however a program objective to operate with a one man crew. During the initial test program, a three-man crew was designated by CN to operate the Railbus. Maintenance would be carried out between the morning and evening runs except for bus cleaning and fuel top-off carried out last thing at night. The non-passenger testing was carried out on a basis of one complete round trip, each day, Monday to Friday.

Railbus operation was eventually scheduled three times a week as shown in Table 2 for passenger demonstration.

TUESDAY (THOMPSON-THICKET PORTAGE)	THURSDAY (THOMPSON-PIKWITONEI)	SATURDAY (THOMPSON-THICKET PORTAGE-PIKWITONEI)
DT 0800	DT 0800	DT 0800
ATP 0935	AP 0945	ATP 0935
DTP 0950	DP 1000	DTP 0950
AT 1125	AT 1145	AP 1100
		DP 1115
		AT 1300
6 hours layover	6 hours layover	6 hours layover
DT 1730	DT 1800	DT 1900
ATP 1905	AP 1945	ATP 2035
DTP 1920	DP 2000	DTP 2050
AT 2055	AT 2145	AP 2200
		DP 2215
		AT 2359

SYMBOLS

D - Departure
A - Arrival
T - Thompson
TP - Thicket Portage
P - Pikwitonei

TABLE 2: PASSENGER DEMONSTRATION TIMETABLE

5.2 SUMMARY OF TEST RESULTS

The WCSS Railbus was tested under various weather conditions on CN Rail track in non-passenger service. (9) During the period of 27 April - 11 May, 1986, the vehicle was accepted for non-passenger operation on CN Rail track and was operated by CN Rail operating personnel. The operation testing area on CN Rail was located between Thompson-Pikwitonei-Thicket Portage.

The CN Rail personnel were UCOR-qualified employees, with support from TTL test personnel.

During non-passenger testing of the WCSS Railbus on CN Rail track, it was concluded that the vehicle could be successfully operated in passenger service. It was noted that vehicle interior noise levels were excessive, due to the location of the engine in close proximity to the operators.

During the CN Rail non-passenger test period of 27 April - 11 May 1986, operation of the WCSS Railbus vehicle by CN Rail operating personnel revealed some areas where further modifications were required on the WCSS Railbus.

These vehicle modifications were undertaken by TTL test personnel on 10-11 May 1986, in Thompson, Manitoba. The final vehicle modifications made included:

- CN-type locomotive whistle installed;
- locomotive whistle air reservoir installed;
- vehicle air line check valve installed;
- engine fan belts replaced;
- vehicle classification - marker lights improved;
- smaller vehicle whistle removed;
- vehicle washroom amenities improved; and
- vehicle operating radio improved.

CN Rail inspected the vehicle after the above vehicle modifications were completed and were satisfied that these modifications would eliminate the deficiencies noted during the non-passenger test period.

Total miles accumulated during the non-passenger portion of the test trial while on the CN Rail Line amounted to 1190 miles (1903 km).

5.3 SUITABILITY OF VEHICLE FOR PASSENGER OPERATION

The testing of the WCSS Railbus in non-passenger service on CN Rail track revealed the following conclusions:

- CN Rail operating personnel could successfully operate the WCSS Railbus with a minimum of instruction and teaching time;
- all of the operating features incorporated into the WCSS Railbus design could be safely operated;
- the WCSS Railbus vehicle could be successfully and safely operated on CN Rail track in passenger service;
- operational characteristics of the WCSS Rail Bus vehicle allowed a minimum of operating personnel; and
- non-revenue passenger service carrying tests be carried out as soon as possible.

6.0 VEHICLE OPERATION AND ASSESSMENT ON CN LINE - PASSENGER SERVICE

6.1 DESCRIPTION OF PASSENGER SERVICE DEMONSTRATION

Following the correction for vehicle deficiencies as requested by CN, non-revenue passenger service demonstrations was undertaken on the CN line between Thompson, Thicket Portage and Pikwitonei from June 26 to June 28 1986 and August 26 to 30 1986 (10). A routine schedule planned for a limited number of two round trips per day was to be undertaken using the Railbus. Operating times to be followed during this final phase of the test program were as outlined in Table 2:

During the demonstration period, a total of 9 round trips were completed and each round trip equalled approximately 118 miles (190 km). The seating capacity of the WCSS Railbus in its normal configuration was 28, including the drivers seat. The three-man CN designated crew operated the vehicle with one TTL test personnel aboard as an observer for the first week of service. The third CN employee (actually a supervisor) was then deemed to be unnecessary and further operation proceeded with a two-man crew. In addition to luggage racks on each side of the bus above the seats there was space for luggage on and below the stretcher table and three compartments available for passenger luggage below the bus floor (accessible from outside the bus).

Approximately a total of 300 passengers volunteered for the free passage and 840 miles (1344 km) was accumulated in the total five days of service provided.

Public acceptance of the service being provided was generally enthusiastic. It was not unusual to have passengers waiting in line at the stations unable to find a seat aboard. How much of this is due to the novelty of the free service is not known. Alternate methods of distributing passes to passengers were suggested in order to discourage those who might be using the service as a joy ride and depriving the needy from the use of the limited seating arrangements. During the course of the test program the number of people taking a round trip in the evening was observed to increase to over half the vehicle's seating capacity.

6.2 SUMMARY OF RESULTS

With the exception noted below there was virtually no mechanical or operational problems of any kind during the period of test and the turntable system operated satisfactorily. Minor electrical faults, namely burning out of lamp filaments, occasionally caused minor inconveniences, however, spares carried on-board temporarily corrected the problem. Total distance accumulated during the two phases of the winter test and passenger service demonstration totalled 4960 km. Average fuel consumption was 26.5 litres/100 km.

On Saturday, 30 August, during its initial run out of Thompson, the left wheel of the WCSS 001 Railbus prototype failed while in service. The vehicle was brought to a halt safely and all 14 passengers and crew were returned to their original destinations. The following section summarizes the vehicle failure and its impact on the Railbus program.

6.2.1 Wheel Failure Assessment

Upon examination it was observed that the left front wheel had severe cracking around the mounting studs and would have failed completely if the vehicle had been allowed to continue its journey (See Figure 5). Inspection by TTL of the remaining vehicle wheels also revealed the possibility of a problem with the right front wheel.

On Saturday August 30, the following further emergency actions were taken:

1. The passengers were returned to Thicket Portage by local All Terrain Vehicle (ATV) transportation (approximately 3 miles).

2. The CN Auxiliary at The Pas was initially called out to retrieve the vehicle then cancelled based on further actions detailed below.

3. The local CN Roadmaster responded to radio discussions between TTL & CN. Vehicle retrieval involved placing a railroad tie below the pilot which supported most of the weight normally carried by the front wheels. The wheel flanges remained sufficiently engaged with the track to provide guidance.

4. The vehicle was driven slowly under its own power to Thicket Portage and stored on a siding.

5. After performing further inspection and taking photographs of the failure, the CN crew and TTL train rider were returned to Thompson with the assistance of the CN Roadmaster.

In order to bring the Railbus back to Thompson, the four spare wheels delivered to INCO at Thompson were located and the services of INCO were arranged for.

The wheels were sandblasted, inspected and crack tested at Thompson by TTL and INCO employees. One wheel was rejected on the basis of prior damage to mounting holes. One wheel was rejected based on cracking around mounting holes. The two remaining wheels were judged to be acceptable for at least the 45 mile return trip to Thompson (without passengers).

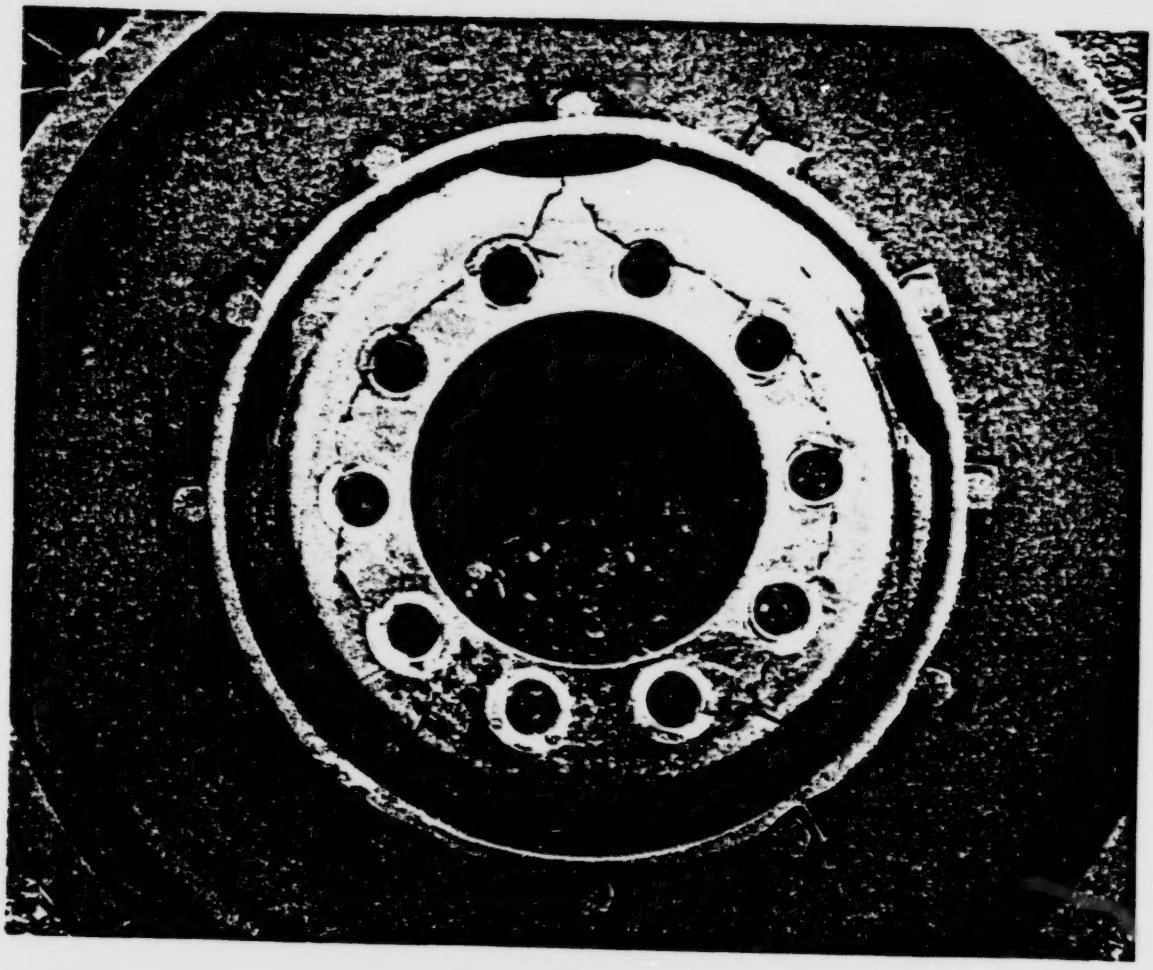


FIGURE 5: RAILBUS WHEEL FAILURE - LEFT HAND FRONT

The wheels were later transported to the Railbus together with a TTL engineer and support personnel and on-site emergency repairs were completed. The WCSS Railbus was returned to Thompson where a more thorough investigation was carried out.

As a result of TTL's engineering analysis report (See Appendix A-2), it was concluded that the Railbus, with its present wheel configuration, should be withdrawn from passenger service. The following steps were suggested by TTL as a minimum to re-establish passenger service with the WCSS Railbus:

- Redesign the wheel hub for the WCSS Railbus with a minimum of parallel changes to the rest of the vehicle;
- Calculate results of wheel changes on other bus components such as wheel bearings;
- Fabricate sample wheel;
- Fatigue test sample wheel on test rig;
- If life cycle targets are met, fabricate a set of wheels and spares;
- Retest wheels on railbus in non-passenger service including:
  - dynamics, switching, curving
  - ride
  - noise and vibration
  - axle loads
- Assess and review modification with TDC and gain CN, CTC approval; and
- Return vehicle to non-revenue passenger service.

The minimum change solution to provide a sound suspension and wheelset for the railbus would involve significantly more than just the design of a new wheel hub for WCSS 001. Invariably any new wheel hub design, whether based on a heavier standard road wheel or designed from scratch, would result in a stiffer "primary" suspension. This could result in higher dynamic loads on the bearings, axles, suspension components and possibly the bus body. All of these factors would have to be analyzed to determine the overall impact on the integrity of WCSS 001.

6.3 CONCLUSION OF PASSENGER SERVICE DEMONSTRATION

All of these factors considered, the minimum change solution was anticipated to be technically feasible, but likely result in a

limited life of axles, bearings, and suspension components. In view of these factors and limited funding available to correct the vehicle design deficiency, the continued evaluation test of the Railbus concept was terminated by Transport Canada.

7.0 CONCLUSIONS AND RECOMMENDATIONS

7.1 CONCLUSIONS

The following conclusions were drawn based on the test program and analysis carried out.

- o The added features to meet the requirements of CN Rail and the CTC authorities improved the vehicle's serviceability, reliability, performance and measured level of passenger and driver comfort.

- o The operating rules, practices, and procedures employed during the tests created a safe environment for the operation of the WCSS railbus on CN lines.

- o The vehicle conversion modifications which enabled it to operate on railway lines have resulted in its satisfactory performance in terms of:

  - stability;
  - curving;
  - switching;
  - braking; and
  - traction.

- o The modified turntable design proved to be reliable and safe for regular vehicle operation. After rework and strengthening, operational tests were conducted at cold weather conditions and it performed satisfactorily at -40°C.

- o Emergency heater operation, and output, in event of engine failure, proved to be inadequate.

- o The degree of controllability of both normal and emergency (dead-man) braking and acceleration is extremely good by rail vehicle standards as both foot-operated controls have retained the bus feature of continuous variability. This enables the driver to stop wheelspin or sliding very quickly.

- o Redesign of the railbus wheels and retesting of the vehicle would be required before any further passenger demonstration could take place.

In summary it is concluded that the vehicle was found to be suitable for a limited passenger demonstration in remote service operation.

7.2 RECOMMENDATIONS

Review of vehicle operations has led to the following recommendations to be noted for implementation before future passenger demonstration service:

- The Railbus wheels be redesigned and the vehicle retested as outlined in Section 6.2. if further demonstration is to be carried out.
- Further development of a "railbus specific" category of vehicle regulatory requirements is required to take into account the differences between remote service railbus operation and conventional rail operation with locomotives and trains.

8.0 REFERENCES

1. "Testing of the WCSS Railbus on the INCO Railway Line", (TP7414E) December 1985.

2. "Detailed Work Plan for Winter Testing and Passenger Demonstration of WCSS Railbus on CN Lines", TTL Report No. 338-920-001, December 1985.

3. "Field Report, WCSS Vehicle Modifications", TTL Report No. 338-660-001, February 1986.

4. "WCSS Railbus Vehicle Preparation for Winter Testing", TTL Report No. 338-660-002, March 1986.

5. "Test Plan for Acceptance and Winter Testing of WCSS Railbus on CN Lines", TTL Report No. 338-650-001, February 1986.

6. "WCSS Railbus Winter Evaluation Testing on INCO Rail Line", TTL Report No. 338-670-001, April 1986.

7. "CN Assessment - WCSS Railbus Operation", TTL Report No. 338-580-001.

8. "Operational Strategies for Passenger Service Demonstration", TTL Report No. 338-650-00[illegible], March 1986.

9. "Non Passenger WCSS Railbus Testing on CN Rail Track", TTL Report No. 338-660-004, July 1986.

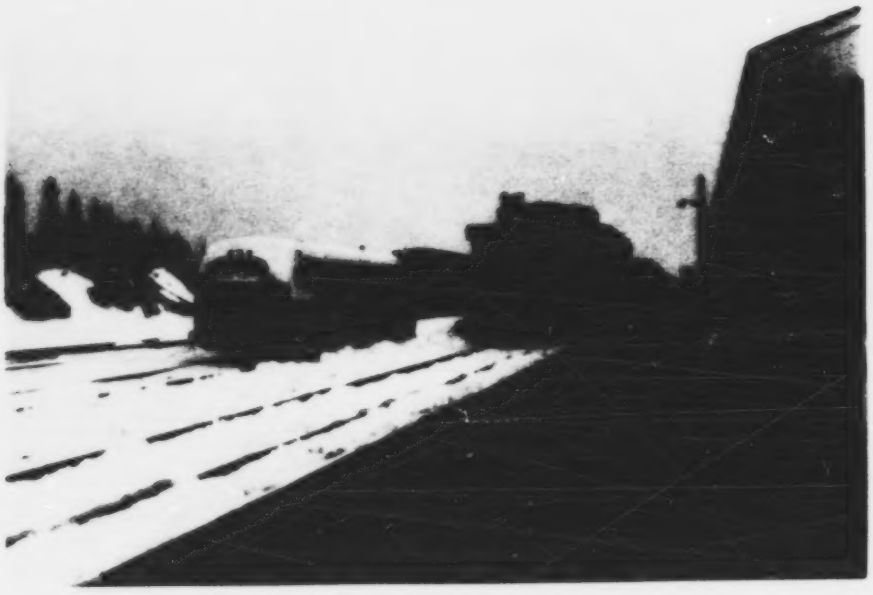
10. "Non-Revenue Passenger Service Report", TTL Report No. 338-660-003, July 1986.

11. Railbus Programme. Request for Authorization to CTC submitted by TDC to Secretary, Mr. J. O'Hara, October 1985.

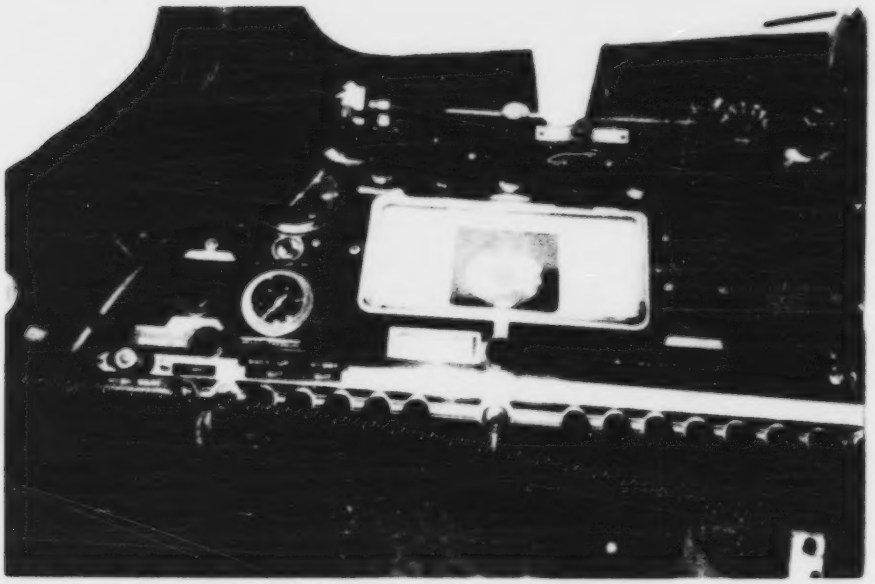
APPENDIX A-1

PHOTOGRAPHIC RECORD OF TEST PROGRAM

WCSS RAILBUS ARRIVES CN THOMPSON STATION FROM INCO LINE APRIL 29, 1986.

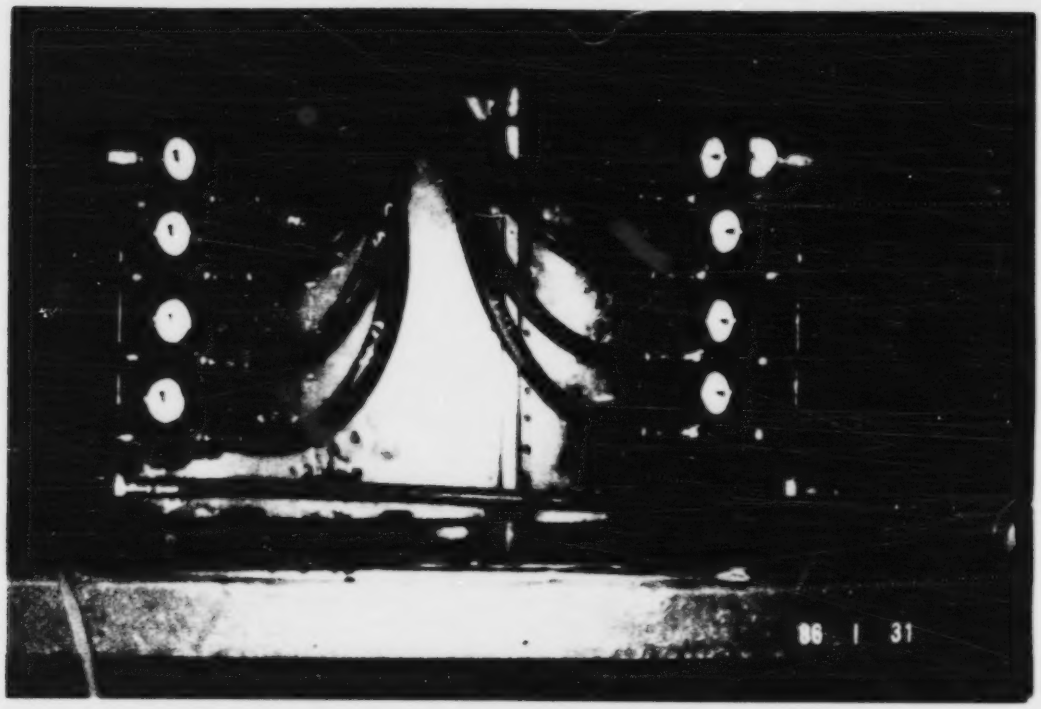


WCSS RAILBUS AWAITS DEPARTURE AT THOMPSON STATION ON NON-PASSENGER DEMONSTRATION SERVICE

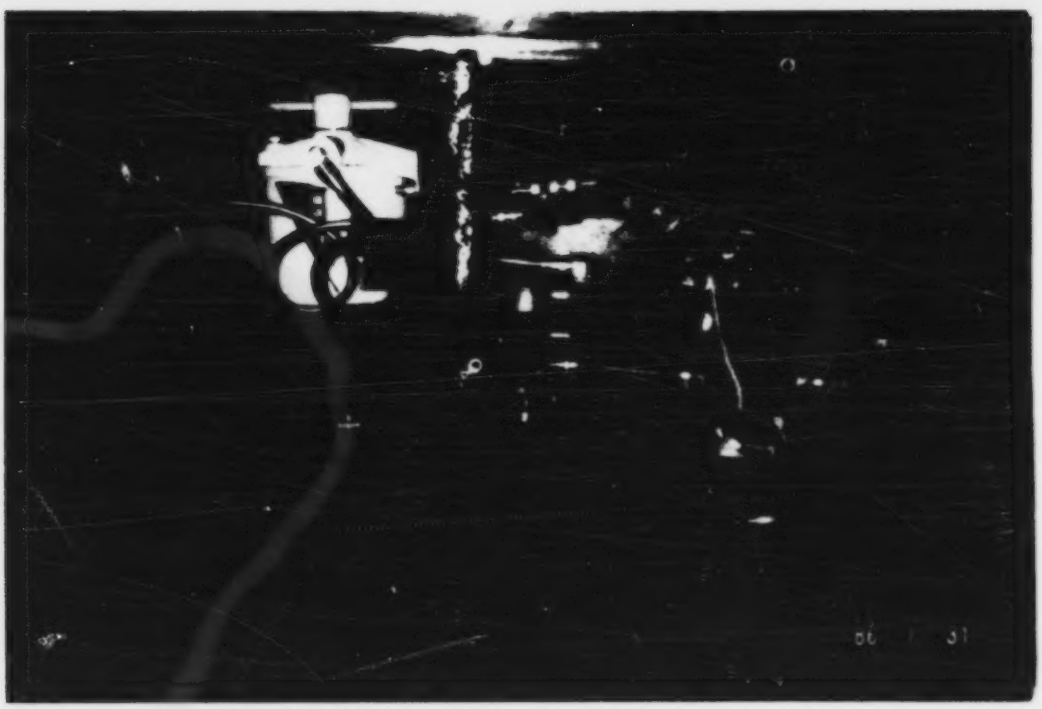


DRIVER CONTROL CONSOLE AND VEHICLE INSTRUMENTATION

MOBILE TELEPHONE, PADDED ENGINE COVER AND TURNTABLE HYDRAULIC CONTROLS

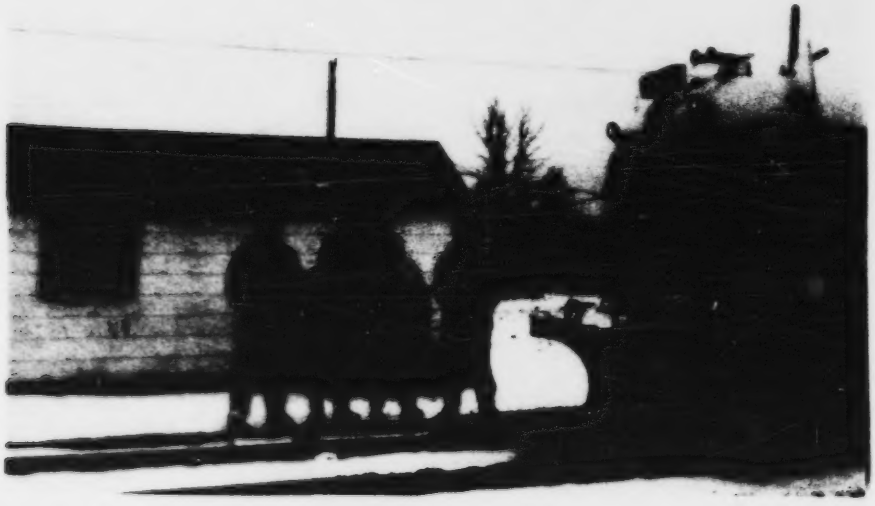


MODIFIED TURNTABLE LIFT-CONTROL CIRCUIT



FUEL HEATER AND WATER SEPARATOR LOCATED AT FUEL TANK

WCSS-1 AWAITING AUTHORIZATION TO LEAVE THOMPSON JCT. TO THICKET PORTAGE. NOTICE FINAL HEADLIGHT CONFIGURATION AND CLASSIFICATION LIGHTS.

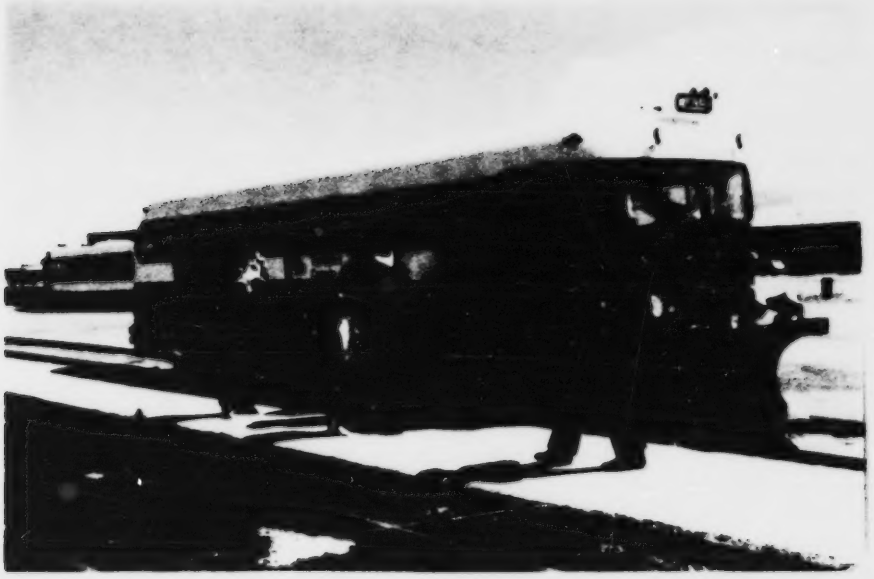


WCSS-1 AT THICKET PORTAGE, DESTINED FOR PIKWITONEI ON APRIL 30, 1986. FROM LEFT TO RIGHT ARE CNR ENGINEER, MAYOR OF THICKET PORTAGE, TTL TEST ENGINEER AND CNR TRAILMASTER

FIRST PASSENGERS DURING NON-REVENUE SERVICE DEMONSTRATION, JUNE 26, 1986.

RAILBUS ARRIVAL AT PIKITOWNE!

INTERIOR OF RAILBUS DURING PASSENGER SERVICE



RAILBUS PRIOR TO SERVICE OUT OF CN THOMPSON STATION

APPENDIX A-2

WHEEL FAILURE ANALYSIS REPORT

WHEEL FAILURE ANALYSIS REPORT

Report No.: 338-540-002

Issue No.: 1

Copy No.:

Originator

SHS

Project Engineer

Date: _____

Project Manager

Date: 86/09/25

SUMMARY

A review of a wheel failure on the WCSS 001 Railbus while operating in non-revenue passenger service out of Thompson, Manitoba is provided.

Inspection results are provided, a stress model is developed, the stress results are analyzed and an estimated life expectancy is determined.

The conclusion is made that the Railbus wheel assembly, as presently configured, is unsafe for passenger service.

Recommendations are made for a method of redesign and retest of the Railbus wheel assembly if it is decided to re-establish the service out of Thompson, Manitoba.

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ATTACHMENTS 1 - TTL/1651/86, Letter to TDC, 9 September 1986

1.0 INTRODUCTION

A Western Flyer bus was converted during 1984 for operation on railway tracks by Winnipeg Coach Sales and Service (WCSS) Ltd. This vehicle served as a test vehicle for evaluation of related engineering design concepts, addressing institutional and regulatory issues, and assessment of the overall feasibility of railbus operations in northern remote communities. A demonstration passenger service was initiated for northern Manitoba on 26 June 1986, linking Thicket-Portage and Pikwitonei with the City of Thompson.

Preliminary vehicle operational tests were originally conducted by WCSS on the tracks of the Greater Winnipeg Water District Railway in Winnipeg, Manitoba.

Transportation Technology Limited (TTL) became involved in the next stage of development testing during which the railbus was significantly modified and underwent a series of intensive operational trials on railway lines owned by INCO Limited in Thompson, Manitoba.

The tests were undertaken on the INCO line due to its accessibility for test purposes, no other traffic to cause interference, and the continuing support of the program by INCO.

The Transportation Development Centre (TDC) has been closely involved with the project since its inception and contracted with WCSS for the earlier program during which the vehicle conversion to rail operation was carried out. Transport Canada subsequently purchased the railbus from WCSS.

2.0 BACKGROUND

Unanticipated vehicle wheel structure failures occurred on 30 August 1986, which caused the subject test program to be stopped. In this incident, the WCSS 001 railbus, designed and manufactured by subcontractors to TDC prior to TTL involvement experienced a critical failure with its wheels. Timely action, by the on-board attendant, fortunately avoided a potential derailment with 14 passengers aboard. Emergency action was taken in order to accommodate stranded passengers, analyze the problem and effect those repairs necessary to permit return of the vehicle to Thompson, Manitoba. The vehicle is now disabled and awaiting final disposition in Thompson, Manitoba.

Details of the actions taken pertaining to this wheel failure are reported in Attachment 1 of this report and relate to the discovery of a severely cracked left hand front wheel hub.

3.0 INSPECTION AND TEMPORARY REPAIR

The inspection of the Railbus wheels and temporary repair was carried out in several stages.

1) At the time of failure, a visual and photographic inspection was made.

2) The spare wheels in Thompson were sandblasted and inspected for cracks.

3) All four original wheels were again inspected visually at the time of replacement of the two original front wheels with the two suitable spare wheels.

4) The original rear wheels were sandblasted and inspected for cracks at INCO after the Railbus was returned to Thompson.

3.1 INITIAL INSPECTION

The initial inspection of the failed left hand front wheel was carried out by TTL staff 30 August 1986, as outlined in Attachment 1. Photographs were taken of the damaged wheel at that time which show very clearly the extent of damage to the cracked wheel hub (See Figure 1). The other wheels on the Railbus (WCSS 001) were also visually inspected at that time with the result that the rear wheels appeared to be crack free, where as the front right hand wheel appeared to have some evidence of cracking between the stud mount holes on the wheel hub.

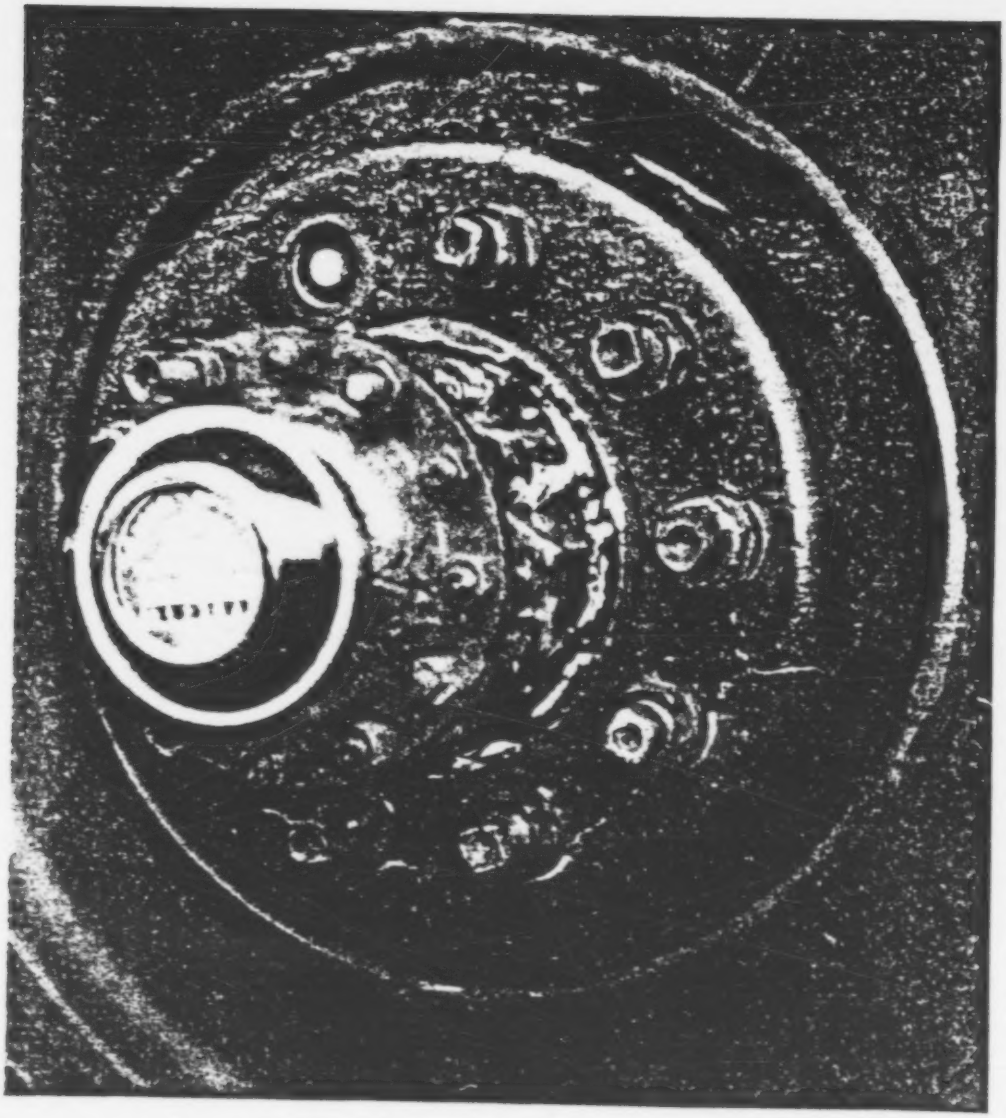


FIGURE 1: LEFT HAND FRONT WHEEL WHEN FAILURE FIRST DISCOVERED

3.2 SPARE WHEELS INSPECTED

The four spare wheel assemblies stored in Thompson, were then sandblasted and inspected by magnetic particle techniques at INCO under TTL supervision.

One wheel was found to be severely damaged at the stud mount holes. The damage to this wheel appeared to have resulted from an oxygen/acetylene cutting torch followed by an attempted weld repair of the wheel nut seat area. This wheel was rejected.

A second wheel was found to have cracks propagating from several stud mount holes (See Figure 2). This wheel was rejected.

The remaining two wheels appeared to be free of cracks in the area of the stud mount holes when inspected on both the inside and outside mount faces of the wheel hub. These wheels were accepted for the Railbus recovery from Thicket-Portage to Thompson (without passengers).

3.3 INSPECTION OF ORIGINAL WHEELS AT TIME OF REPLACEMENT

The following check list of tasks was used to inspect the wheels when the front wheels were replaced on Friday, September 5.

1) Photograph front wheels in place.

2) Check torques of all wheel nuts as they are removed.

3) Remove front wheels and inspect brake drum and inside of wheel hub mount face.

4) Inspect and replace damaged studs.

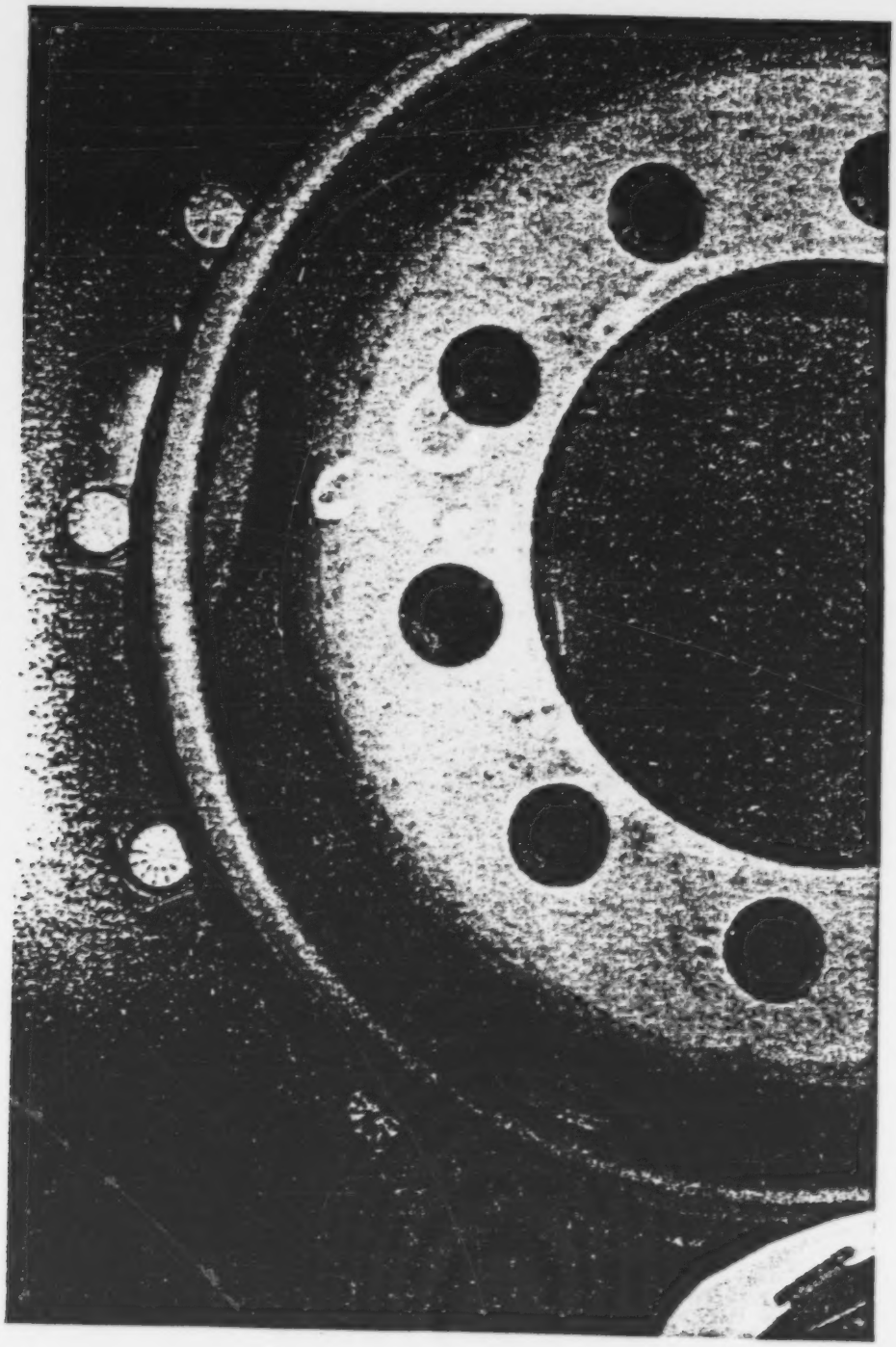


FIGURE 2: CRACKED SPARE WHEEL

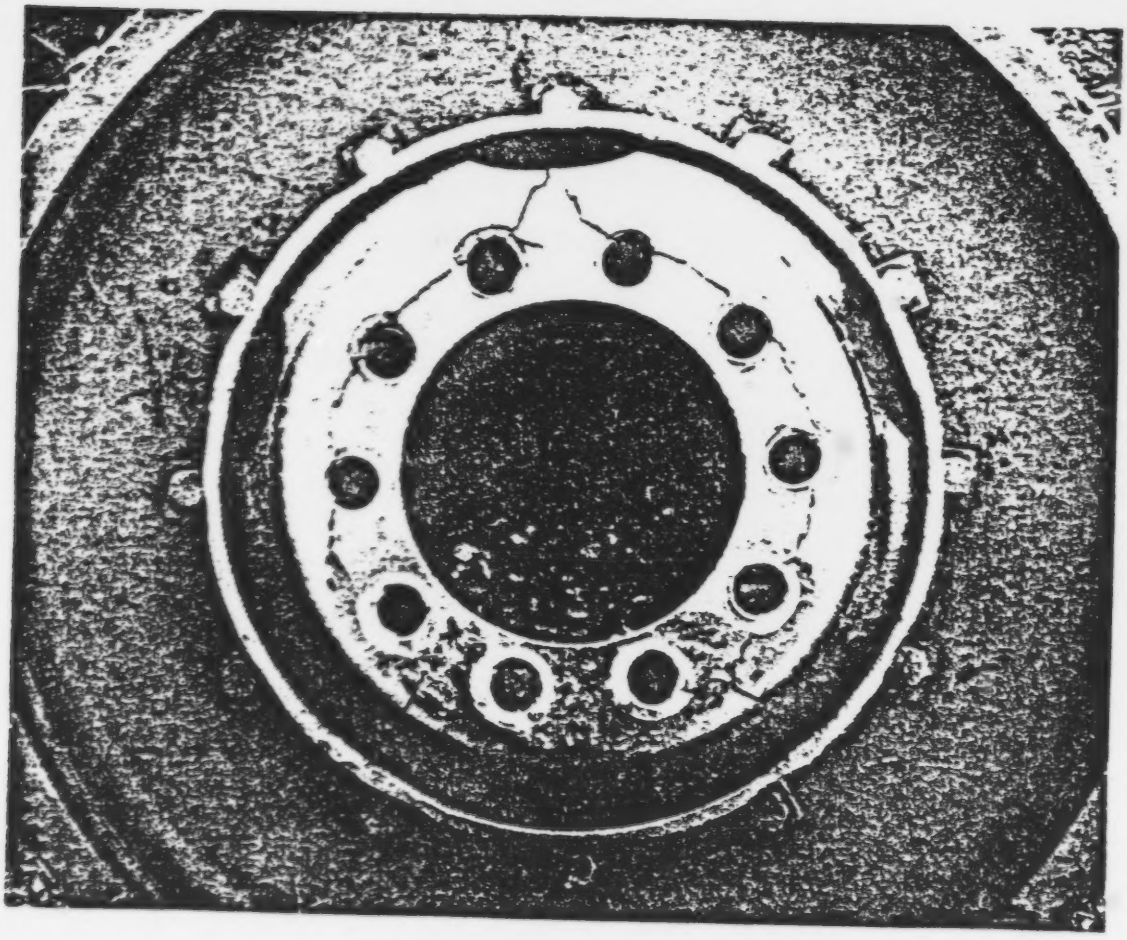


FIGURE 3: LEFT HAND FRONT WHEEL AFTER REMOVAL FROM WCSS 001

5) Inspect rear wheels for cracks.

6) Check torque on rear wheel nuts.

7) Install two spare wheels on front of Railbus.

8) Remove railwheel rims from wheel hubs of two original front wheel assemblies and ship wheel hubs to Kingston.

9) Re-torque nuts on front wheels to 425 ft-lbs.

The results of the visual and photographic inspection of all wheels confirmed the original inspection results. A photograph clearly showing the extent of damage to the left front wheel hub is provided in Figure 3 which was taken after the wheel was removed.

The right hand front wheel hub showed very slight indication of cracking. The painted surface and corrosion of the hub made inspection difficult.

The rear wheels did not show visible evidence of cracking on the outside of the wheel hub (these wheels were not removed). The torque on all wheel nuts was checked after the safety nuts were removed and are listed in Table 1. The desired torque level was 400-500 ft-lbs. From Table 1 it can be seen that the right hand front wheel as well as both rear wheels were within the desired limits with the exception of one nut on the right hand front wheel and a total of 3 nuts on the rear wheels which turned slightly (less than 1/32 of a turn) when checked at 425 ft-lbs.

TABLE 1

WHEEL NUT TORQUES (FT-LBS)

STUD NO.	WHEEL LOCATION			
	L.H. FRONT	R.H. FRONT	L.H. REAR	R.H. REAR
1	325	400	425	425
2	200	400	425	425
3	Broken stud	500	425	425
4	200	400	425	425
5	300	500	425	425
6	250	400	425	425
7	150	500	425	425
8	Came off with safety nut	400	425	425
9	350	375	425	425
10	250	475	425	425

The low torques on the left hand front wheel nuts are obviously a result of the cracked condition and subsequent scoring of the wheel hub mount face and nut seats. Essentially, the wheel nuts were only retaining the cracked inner section of the wheel hub. The safety nuts were in fact the only means by which the wheel was physically retained to the axle. After installation of the spare front wheels, all wheel nuts were torqued to 425 ft-lbs.

The studs in both front wheels were inspected and those which were immediately suspect by visual inspection were replaced. Only studs in the left hand front wheel appeared to require replacement for the recovery trip to Thompson. All studs are of unknown history since none were new when the Railbus was originally converted, but no new studs of the correct type could be located in time for vehicle recovery. The studs which were replaced are as follows:

- #1 Stud was replaced 500 miles before the wheel failed since it was found to have broken.

- #2, #3, #4, #5, #6, #7, #8, #10 studs were replaced with other second hand studs at the time of installation of the spare wheels.

The left hand front wheel mount face and the mating surface on the brake drum were severely scored (See Figure 4) as a result of the movement of the wheel under the safety nuts (approximately 1/8 inch deep). Also, the contact area under the safety nut was severely scored due to the wheel movement (approximately 1/16 inch deep).

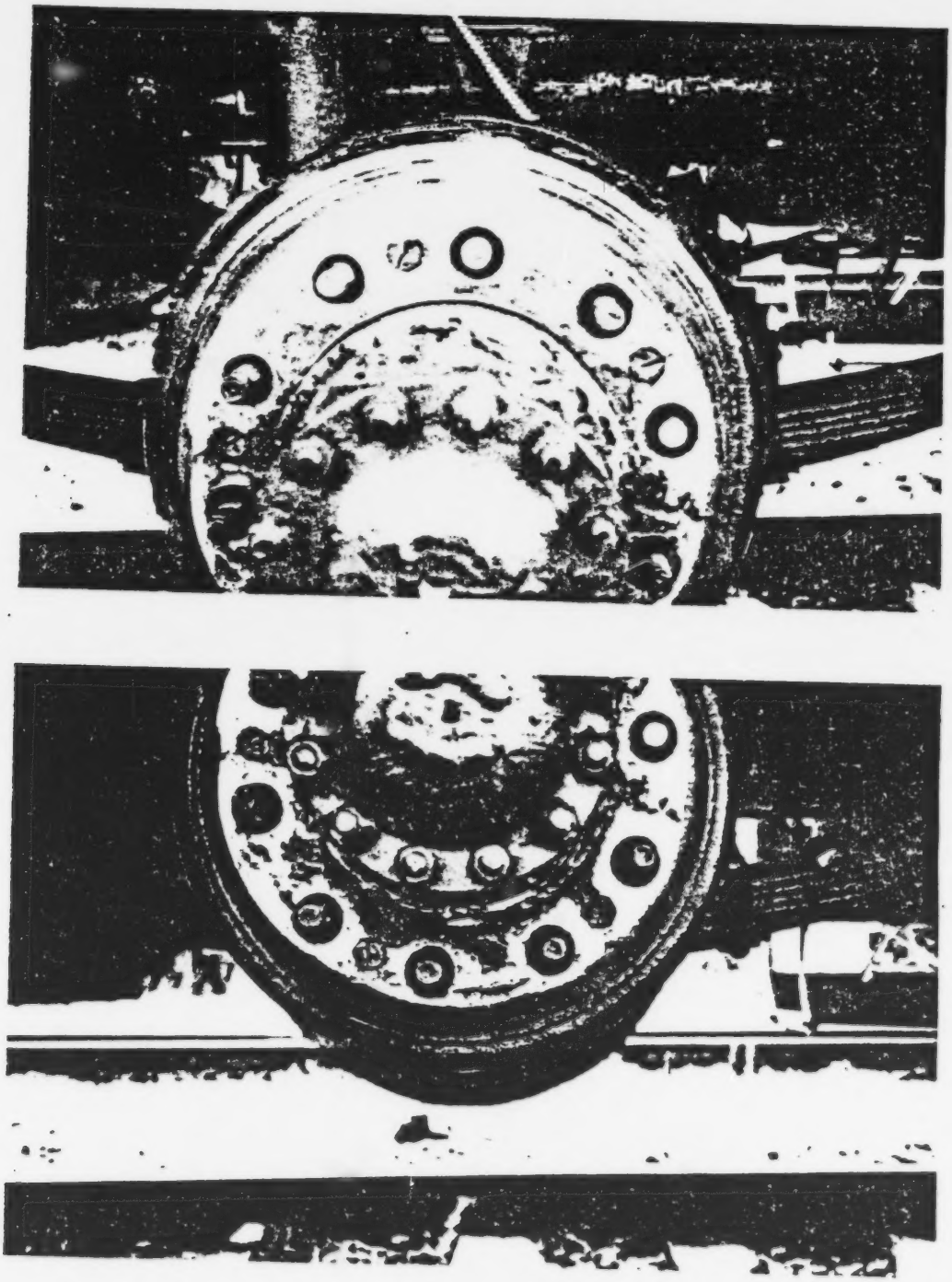


FIGURE 4: SCORING OF WHEEL MOUNT SURFACE ON BRAKE DRUM

3.4 INSPECTION OF ORIGINAL REAR WHEELS

After the recovery of the WCSS 001 from Thicket to Thompson was completed, the rear wheels were removed.

These wheels were sandblasted and inspected by INCO under TTL supervision using magnetic particle techniques. Both wheels were found to have small cracks originating from the stud mount holes. It was not clear, from the inspection, whether the cracks actually originated from the inside mount face of the wheel hub, or the outer face.

4.0 ANALYSIS

The analysis carried out here quantifies the actual wheel loads including the number of cycles at those loads, develops a model which is intended to simulate the stress conditions of the actual wheel and discusses the resulting strength and theoretical life of the wheel hub. The analysis is limited to the area around the stud mount holes as this is where the cracking appears to have been initiated.

4.1 WHEEL LOADS

The wheel loads are based on actual static wheel load test data recorded in Appendix A of Reference 1.

Static Loads

Location	Vehicle Unloaded (lbs)	Vehicle Loaded (lbs)
Front R.H. Wheel	4,528	5,226
Front L.H. Wheel	5,594	6,222
Rear R.H. Wheel	6,452	7,708
Rear L.H. Wheel	6,083	7,340
Total	22,730 lbs	26,500 lbs

Vertical Static Load (F_{VS})

o Assume the worst case for wheel loading will be typical:

	Unloaded	Loaded
Wheel Load at Rail -	6452 lb	7708 lb
Less Wheel Weight -	450 lb (estimated)	450 lb
Vertical Static Load	6002 lb	7258 lb

Lateral Static Load (F_{ls})

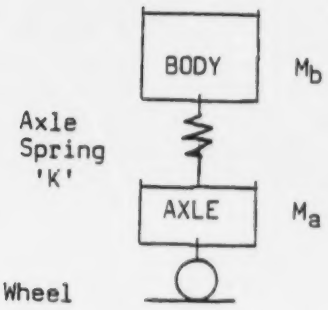
The lateral static wheel load is zero

i.e. $F_{ls} = 0$

Dynamic Wheel Loads

o The following values are estimated for the weight of vehicle components over each wheel assembly:

	Unloaded	Loaded
Body (M_b).....	5527 lb	6783 lb
Axle Spring (M_a)....	475 lb	475 lb
Total	6002 lb	7258 lb



Where: $F_a = M_a A_a$

$F_b = M_b B_b$

A_b = Body Acceleration (G's)

A_a = Axle Acceleration (G's)

- Results of actual test measurements are summarized in the following table:

Note:

- Axle acceleration rates were actual values measured while body acceleration rates were determined from British Ride Meter measurements (fully laden, front-axle); and

- Review of test measurements indicated an amplitude frequency of 3.8 Hz for the average ride index and 0.5 Hz for the peak index.

LOCATION	DIRECTION	ACCELERATION ('G') AVERAGE	PEAK
BODY	LATERAL VERTICAL	.085 (3.8)* .070 (3.3)*	.20 (4.0)* .18 (3.6)*
AXLE	LATERAL VERTICAL	.50 .90	1.50 4.20

* British Rail Measurements

Assume that vertical body and axle motions are in phase and act as one force on wheel hub;

i.e. $F_{vd} = F_{vs} + F_b + F_a$

Assume in the lateral direction, that the dynamic input results from flanging on one wheel only per axle i.e., in the lateral direction;

$F_{ld} = 2 (F_b + F_a)$

Thus, the dynamic forces (F_{vd} and F_{ld}) acting on the wheels are summarized in Table 2.

TABLE 2

WHEEL LOADS (LBS)

		UNLOADED	LOADED
STATIC LOADS	Vertical (F_{vs})	6002	7258
(assumes ideal track conditions)	Lateral (F_{ls})	0	0
DYNAMIC LOADS*	Vertical (F_{vd})	10474	10474
(based on peak acceleration levels)	Lateral (F_{ld})	4138	4138

*Note: Since the test data were taken in the loaded condition, the dynamic loads are calculated for the loaded condition and then assumed to be identical for the unloaded condition thus resulting in higher body and axle acceleration levels for the latter case.

Load Cases

A series of four load cases for both the loaded and unloaded conditions was then compiled in order to support a representative fatigue analysis. These load cases along with their estimated number of cycles accumulated at the time of the wheel failure are listed in Table 3.

The number of cycles is based on the estimated mileage travelled (taken from the log book) in the loaded and unloaded conditions since TTL began testing WCSS 001 as follows:

	Miles
Unloaded	4057
Loaded	945
Total	5002

4.2 STRESS ANALYSIS MODEL

Figure 5 shows a cross-section of the wheel/axle assembly. The area of the wheel hub mount holes is detailed in Figure 6 and is modelled to determine the local stress levels.

4.2.1 Bending Stress

The model used to simulate the stress levels under load was taken from Reference 2, Table 24, cases 20 and 21 (See Figure 7).

Case 20 assumes an annular flat plate disc of thickness 't' is loaded at its inner diameter by a bending moment and the outer diameter is simply supported. Case 21 assumes an annular flat plate disc of thickness 't' is loaded at its inner diameter by

TABLE 3

LOAD CASES

No.	Description	Miles (Estimated)	No. Cycles	
			Per Mile	Total*
1.	(Static) ie. assumes only static vertical load on rotating wheel (empty)	4,057	560	2.30E6
2.	Static (loaded)	945	560	0.53E6
3.	Dynamic vertical (empty) (only vertical dynamic loads)	4,057	135	0.55E6
4.	Dynamic vertical (loaded)	945	135	0.13E6
5.	Combined - static plus lateral shock (empty)	4,057	250	1.01E6
6.	Combined - static plus lateral shock (loaded)	945	250	0.24E6
7.	Combined vertical dynamic and lateral shock (empty)	4,057	10	0.04E6
8.	Combined vertical dynamic and lateral shock (loaded)	945	10	0.01E6

*Note: Only the total number of cycles accumulated under the TTL test program are included in these values. Any previous loading history is not known except that extensive testing with the wheels in "rail" configuration was carried out by others prior to TTL involvement. Also, the wheel hubs were second-hand road wheels when originally converted to rail. In fact a date of 1963 was found on one of the wheel hubs.

Transportation Technology Limited

WCSS Railbus (Project)	Wheel Failure Analysis Report (Title)	Report No. 338-540-002	
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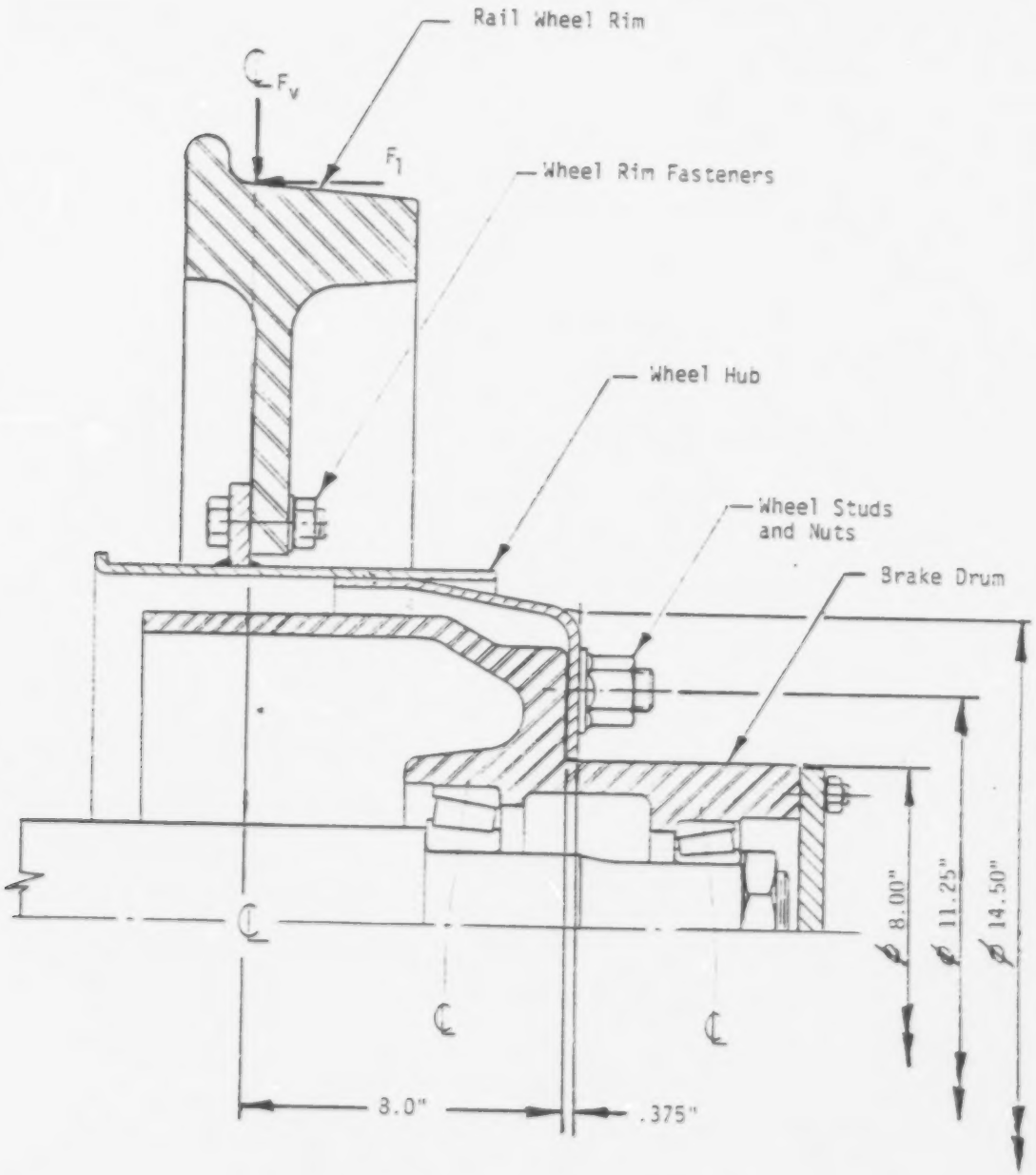


FIGURE 5: WHEEL ASSEMBLY

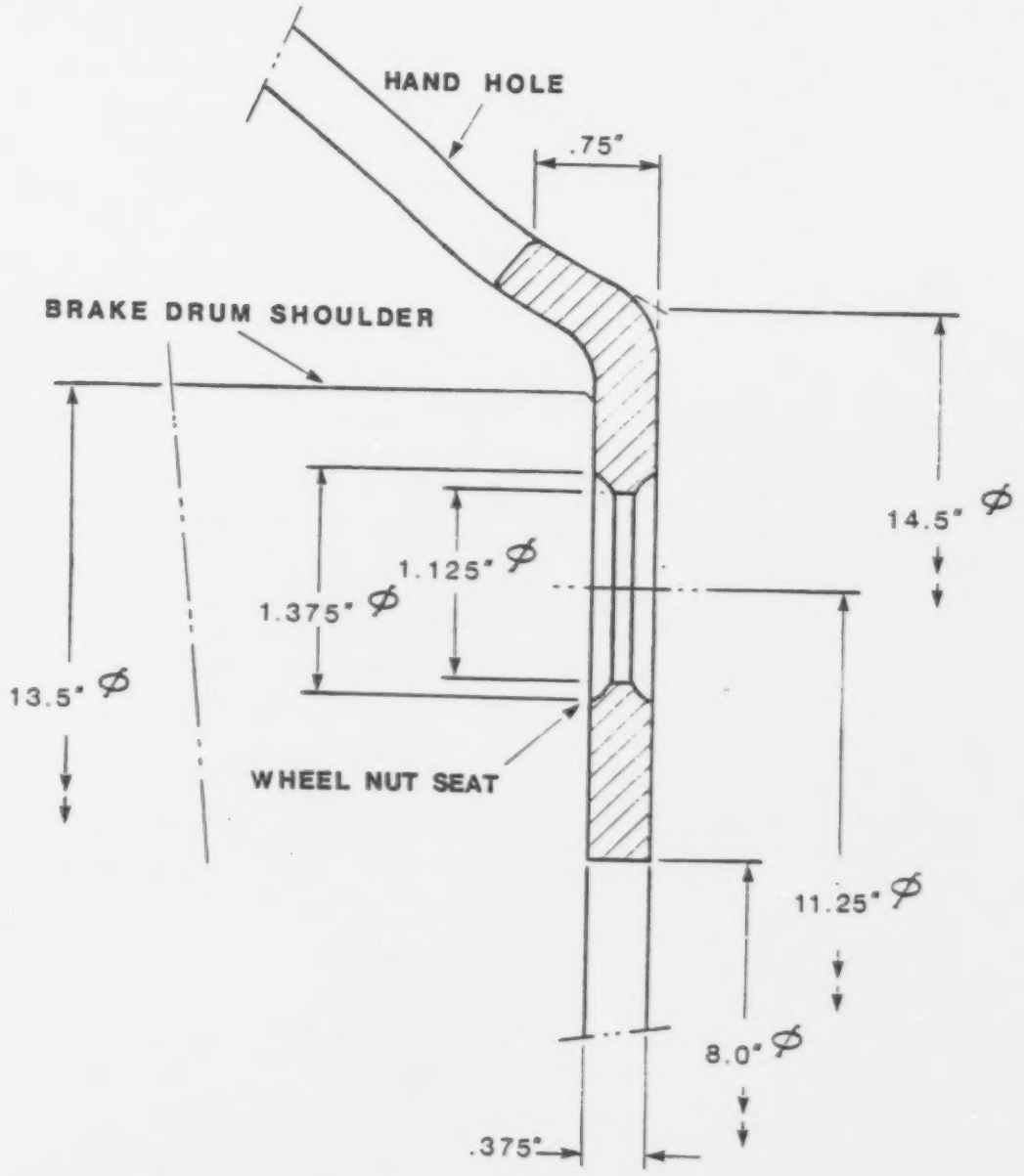
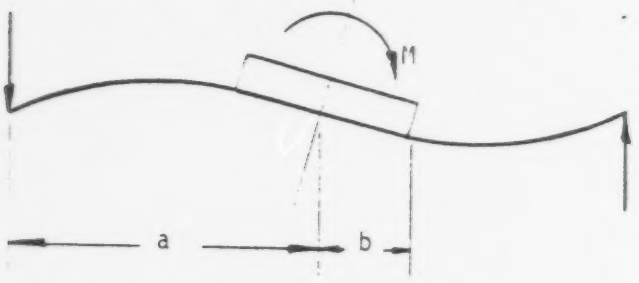
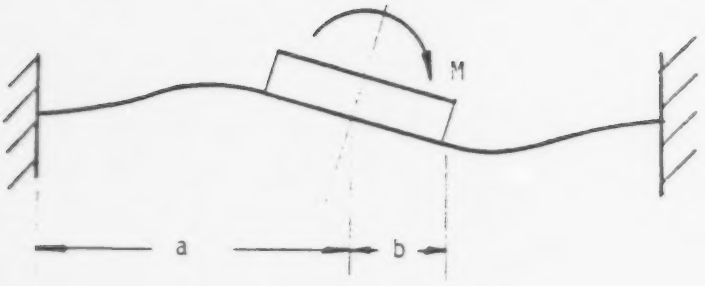


FIGURE 6: DETAILED WHEEL HUB CROSS-SECTION



REFERENCE 2, TABLE 24
CASE 20



REFERENCE 2, TABLE 24
CASE 21

FIGURE 7: STRESS MODEL

a bending moment and the outer diameter is rigidly supported. After giving consideration to the dished shape of the wheel hub, it was assumed that the model closely resembles Case 21 and therefore the stress levels were used directly (ie. assumes that the outer diameter of the "disc" is 100% fixed).

From Reference 2, it was determined that the bending (tensile) stress (σ_{rmax}) resulting from such loading is:

$$\sigma_r = \frac{\beta M}{a t^2}$$

where: β is a function of b/a (See Reference 2)

$\therefore \beta = .326$

a = disc outer radius = 7.25"
b = disc inner radius = 5.625"
t = disc thickness = .375"
M = applied moment = $F_v l + F_l R$
l = moment arm = 8.00"
R = moment arm = 18.00"

In this case, the disc inner radius (b) was taken as the radius to the wheel stud mounting hole centers.

$\therefore \sigma_r = .320 \times M$

This model assumes that no mount holes exist (ie. loss of section due to the mount holes must be considered when determining the stress concentration factor).

Due to the presence of the brake drum shoulder behind the wheel hub, the maximum and minimum bending stresses are:

$$\sigma_{r_{max}} = .320\ M$$
$$\sigma_{r_{min}} = 0$$

4.2.2 Shear Stress

The vertical shear stress (τ_v) is based on a simplified model which assumes that material between the mount holes is under pure shear.

i.e. $\tau_v = \frac{F_v}{A}$

where: F_v = relevant vertical load on wheel

A = effective area

$= (\pi \times b \times 2 - 10 \times d) \times t$

b = 5.625"

d = 1.375"

t = .375"

$$\therefore \boxed{\tau_v = \frac{F_v}{8.097}}$$

Since the load completely reverses, (wheel rotates) the maximum vertical shear fully reverses to $-\tau_v$.

The horizontal shear stress (τ_1) results from the fact that the discrete wheel nuts must support the applied moments due to lateral and vertical loads on the wheel flange and tread respectively.

Assuming that each stud takes equal loads, and assuming that only 8 of the 10 studs are effective in reacting the applied moment, it can be shown that the horizontal load (f_1) applied to each stud wheel nut is as follows:

$$f_1 = \frac{M}{4(\sin 36^\circ + \cos 18^\circ) \times b}$$

where: M = applied moment
b = 5.625"

Using the above horizontal loads, a resulting horizontal shear stress (τ_1) can be determined as follows:

$$\tau_1 = \frac{f_1}{A'}$$

where A' = effective area
$= \pi d t$

d = 1.375"
t = .375"

$$\therefore \tau_1 = \frac{M}{4(\sin 36^\circ + \cos 18^\circ) \times b \times A'}$$

Thus, the maximum and minimum horizontal shear stresses are:

$$\tau_{1max} = \frac{M}{56.09}$$

$$\tau_{1min} = 0$$

4.2.3 Local Tangential and Radial Stress

Due to the spherical seat of the wheel nut in the wheel hub mount holes, local tangential and radial stresses develop as a result of the wheel nut preload (See Figure 8).

The wheel nuts are assumed to be torqued to 500 ft-lbs, and the safety nuts are assumed to be torqued to 250 ft-lbs.

From Reference 3, page 247, the resulting nut preload (fi) can be determined as follows:

$$f_i = \frac{T}{.2d'}$$

where: T = applied torque
d' = nominal thread size

In order to determine the net preload (f_{in}) applied by the inner wheel nut on the spherical seat, the preload on the safety nut (f_{is}) must be subtracted from the preload of the wheel nut (f_{iw}).

ie.:

$$f_{in} = f_{iw} - f_{is}$$

$$f_{in} = \frac{500 \times 12}{.2 \times .75} - \frac{250 \times 12}{.2 \times 1.0625}$$

$$f_{in} = 25880 \text{ lbs.}$$

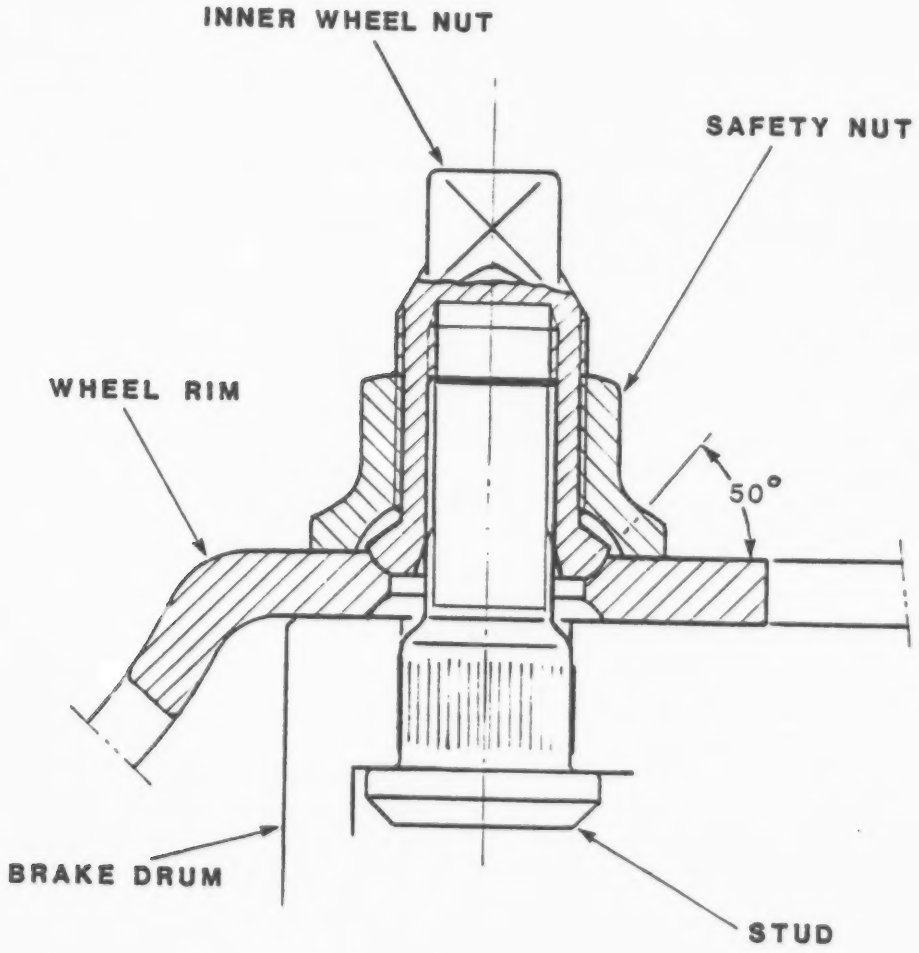


FIGURE 8: WHEEL NUT ASSEMBLY

Assuming this preload is evenly distributed on an approximated effective 50° tapered nut seat over the total thickness 't' of the wheel hub, (note that this latter assumption effectively averages the local stress levels over the entire thickness 't' and thus is somewhat optimistic), the equivalent radial pressure (q) is:

$$q = \frac{f_{in} \times \tan 50^\circ}{\pi \times d \times t}$$

where: d = 1.375"
t = .375"

$$\therefore \quad \boxed{q = 19040 \text{ psi}}$$

Thus from Reference 2 Table 32 case 1(a), an assumed disc of inner radius "b" and outer radius "a", the tangential stress (σ_T) and radial stress (σ_R) are determined as follows:

$$\sigma_T = q \frac{(a^2 + b^2)}{(a^2 - b^2)}$$

and $\sigma_R = -q$

where: a = 2.500"
b = .6875"

Note that 'a' is shown in Figure 9 as being relevant to determine the tangential and radial stress at location "A", being the point from which the wheel cracking appeared to originate.

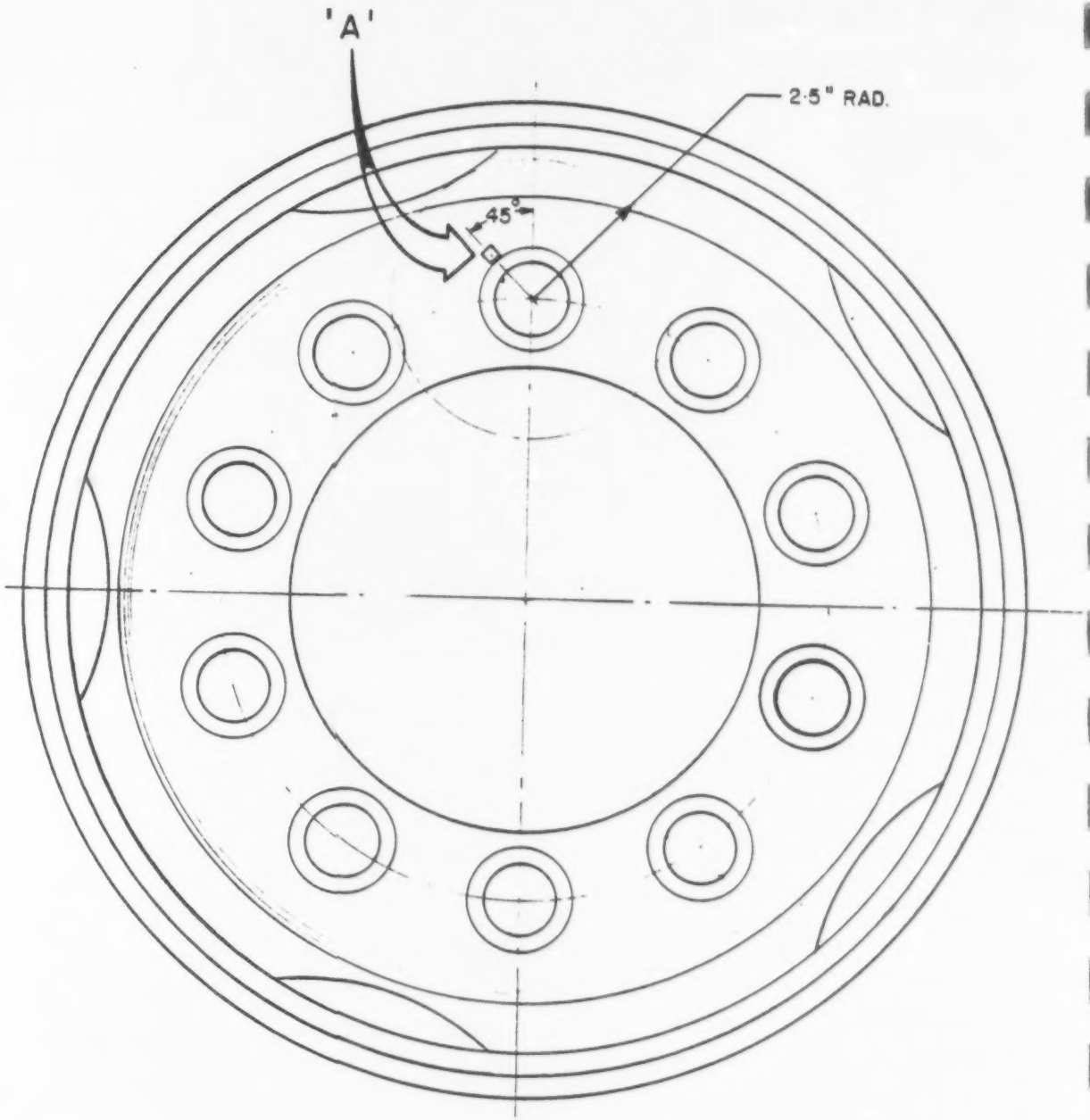


FIGURE 9: EFFECTIVE DISC DETERMINING TANGENTIAL AND RADIAL STRESSES

Thus at location "A":

σ_T = 22155 psi

σ_R = -19040 psi

The maximum and minimum tangential and radial stress levels are equal (ie. do not fluctuate).

4.2.4 Normal and Shear Stresses

Since the wheel hub is supported by the brake drum, and is therefore only free to flex away from the drum, the maximum tensile stress location is on the inside mount face of the wheel hub at location 'A' (see Figure 9).

An element is constructed in Figure 10 which shows all the applied stresses. Based on these applied stresses, the plane shear stresses and normal stresses can be determined as follows:

$\sigma_x = \sigma_R$

$\sigma_y = \sigma_T + \sigma_r$

$\sigma_z = 0$

$\tau_{xy} = \tau_v$

$\tau_{xz} = \tau_l$

$\tau_{yz} = 0$

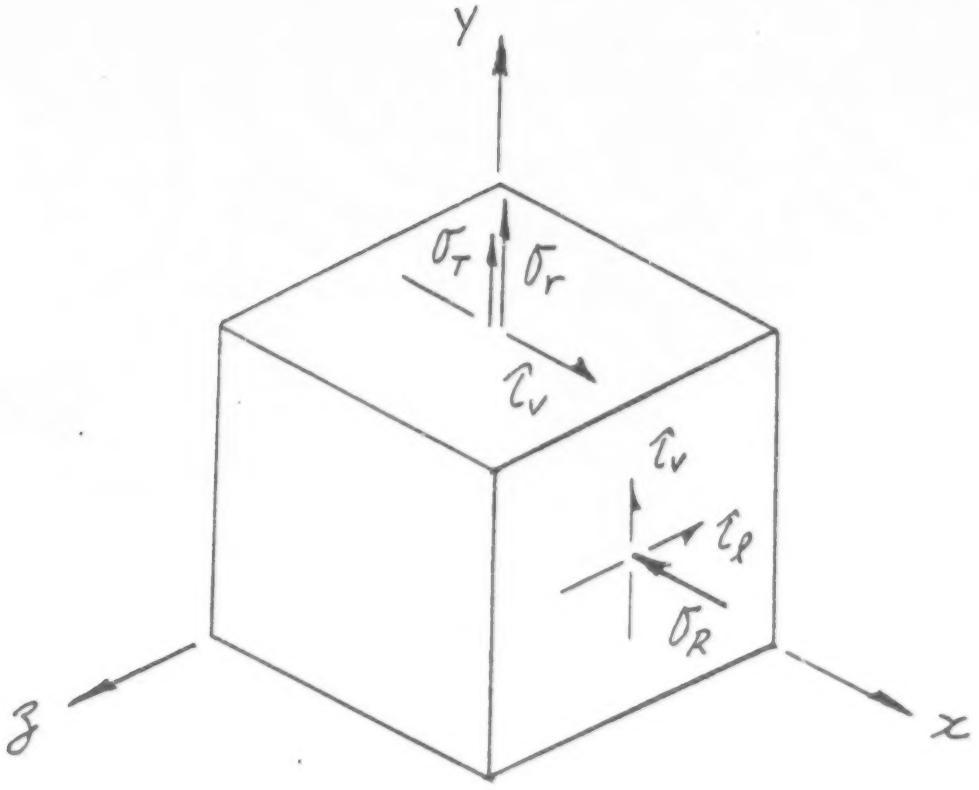


FIGURE 10: STRESS ELEMENT

4.2.5 Principle Stresses

From Reference 3 Page 33, Mohr's Circle for Triaxial Stress can be determined from a third order polynomial. When σ_z and τ_{yz} are set to zero, the polynomial reduces to:

$$\sigma^3 + (\sigma_x + \sigma_y)\sigma^2 + (\sigma_x\sigma_y - \tau_{xy}^2 - \tau_{xz}^2)\sigma + \sigma_y\tau_{xz}^2 = 0$$

The three roots of the polynomial when solved are principle stresses designated as σ_1, σ_2 and σ_3. The polynomial must be solved for both the mean and alternating stress components.

In order to determine the mean and alternating normal and planar shear stress components, the maximum and minimum applied stresses must be used.

4.2.6 von-Mises Stresses

The previously determined mean and alternating principle stresses are used to determine a mean and alternating "equivalent" stress known as von Mises Stresses (σ_m and σ_a).

The von Mises stress can be determined from the following expression taken from Reference 4 Page 86.

$$\sigma = \frac{\sqrt{2}}{2}\left[(\sigma_2 - \sigma_1)^2 + (\sigma_3 - \sigma_1)^2 + (\sigma_3 - \sigma_2)^2\right]^{\frac{1}{2}}$$

4.2.7 Material Properties

Discussions with the original manufacturer of the road wheel hubs indicated that the material used is fully annealed C1018 carbon steel in coil form. The hubs are first blanked out of the coil material, the dished section is hot rolled over a mandrel, followed by punching of the wheel mount holes. A finish machining operation provides the spherical seat. It was estimated that some work hardening takes place in the area of the wheel mount holes as a result of the manufacturing process.

The ultimate and yield strengths of C1018 in this condition are estimated as follows:

S_{ult} = 78000 psi
S_y = 53000 psi

The subject wheel hub is rated by the manufacturer at 7000 lbs capacity for road use. The failure criteria used by the manufacturer involves loading the wheel to 180 percent of the rated capacity and cycling for 10^6 cycles or more in order to represent infinite fatigue life under these conditions.

The load condition specified by the manufacturer when applied to the method of determining stress levels outlined in this report provides a good indication of the fatigue strength of the wheel hub represented by the following von Mises stress condition.

S_{mean} = 46,461 psi
S_{alt} = $\pm$ 12,102 psi

This allows a Goodman Line to be constructed (see Figure 11) through this point. Since this loading criteria represents the infinite life of the part, and since the actual component was tested, under these conditions, obviously, all factors of surface finish, size, reliability, stress concentration, etc. are taken into account. Thus, when the Railbus load conditions are applied to the wheel using the same stress model, then a reasonable comparison can be made and an estimate of the above fatigue factors is not required at this time. (These factors are required to perform the life cycle analysis).

When one considers the Goodman Line diagram (Figure 11), the resulting endurance limit of 29800 psi appears to be quite high. In order to estimate the endurance limit, the following factors are used based on reference 3 sources.

$S_e = k_a k_b k_c k_d k_e k_f S_e'$ = endurance limit

k_a = surface factor = 0.80
k_b = size factor = 0.95
k_c = reliability factor = 0.897
k_d = temperature factor = 1.00
k_e = strength reduction factor = .568 (determined later in
k_f = residual stress factor = 1.00 paragraph 4.4)
$S_e' = 0.5\ S_u$ = 0.5 x 78000

$$S_e = 0.80 \times 0.95 \times 0.897 \times 1.00 \times .568 \times 1.00 \times 0.50 \times 78000$$

$$S_e = \underline{15100 \text{ psi}}$$

This inconsistency indicates that the original assumptions made in the stress model are quite conservative. In fact the probable source of the variance stems from the assumption of what inner radius 'b' is used to model the bending stress (σ_r)

caused by an applied moment. To reiterate the original assumption, the inner radius 'b' was set as the radius to the stud mount hole centers. In retrospect, since the cracking appeared to propagate from point 'A' as shown in Figure 9, a more appropriate radius 'b' used in the stress model would be that radius which passes through element 'A'.

To correct this source of error in the model predictions, a revised model for the bending stress 'σ_r' will be defined by a new radius 'b' as follows:

$$b = (11.25 + 1.375/2)\ /2$$
$$b = 5.969"$$
$$\text{and } a = 7.250"$$
$$b/a = 0.823$$
$$\therefore \beta = 0.215 \text{ (see reference 2, table 24, case 21)}$$

$$\therefore \boxed{\sigma_r = 0.211 \times M}$$

When carried through to the mean and alternating von Mises stresses, this results in a reduced estimate of the material fatigue strength as follows:

S'_{mean} = 42,750 psi (92.0%)
S'_{alt} = 7,930 psi (65.5%)

The above point when used to produce a new Goodman line results in an estimated endurance limit of 17,400 psi (See Figure 11). This reveals the extreme sensitivity of the stress model to the assumption of the effective inner radius used to determine the bending stress 'σ_r'. Since this correction agrees very well with the Reference 3 prediction of the endurance limit of

Goodman Line

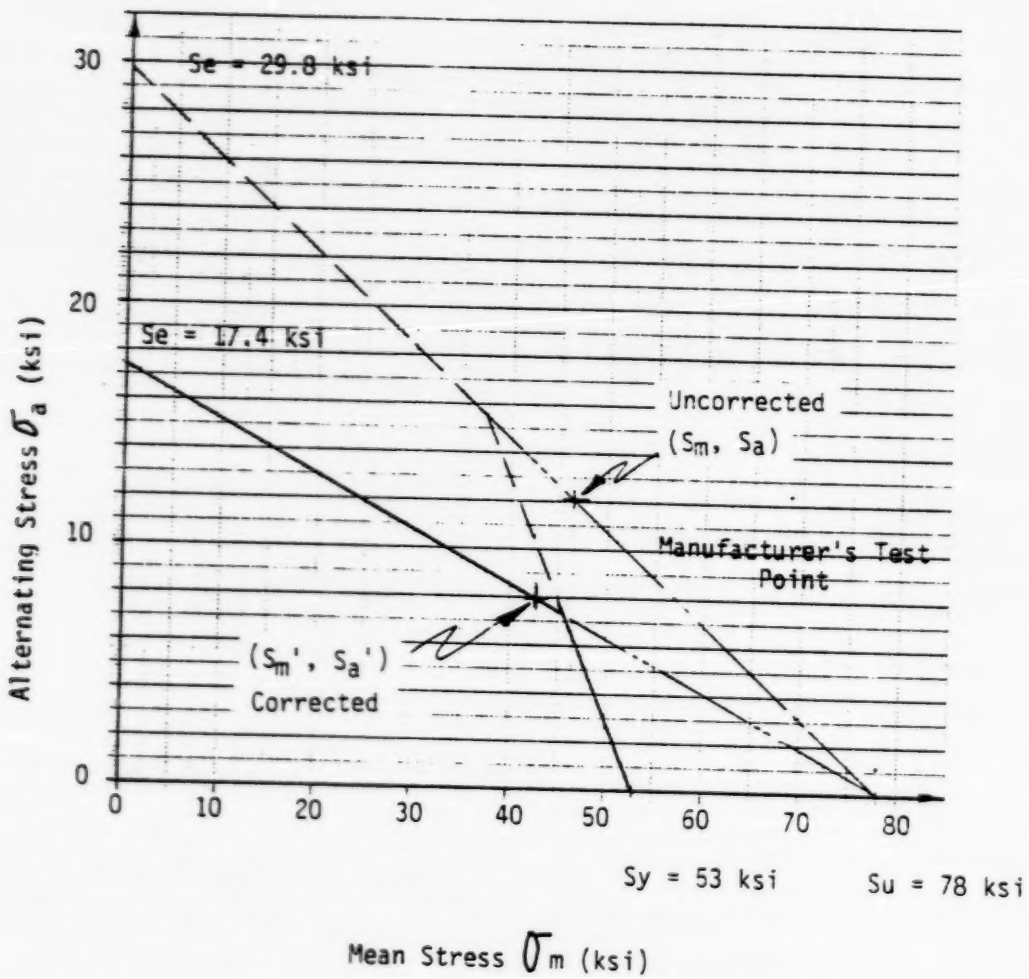


FIGURE 11: GOODMAN LINE

TABLE 4

STRESS RESULTS

LOAD CASE		VON MISES STRESS (psi)	
		UNCORRECTED	CORRECTED
NO.	DESCRIPTION	$\sigma_m \pm \sigma_a$	$\sigma'_m \pm \sigma'_a$
1.	(Static) ie. assumes only static vertical load on rotating wheel (empty)	42679 ± 9000	40279 ± 5278
2.	Static (loaded)	44165 ± 9461	41252 ± 6383
3.	Dynamic vertical (empty) (only vertical dynamic loads)	48018 ± 13654	43761 ± 9212
4.	Dynamic vertical (loaded)	48018 ± 13654	43761 ± 9212
5.	Combined - static plus lateral shock (empty)	53894 ± 19733	47588 ± 13125
6.	Combined - static plus lateral shock (loaded)	55432 ± 21363	48588 ± 14199
7.	Combined vertical dynamic and lateral shock (empty)	59386 ± 25540	51166 ± 17025
8.	Combined vertical dynamic and lateral shock (loaded)	59386 ± 25540	51166 ± 17025

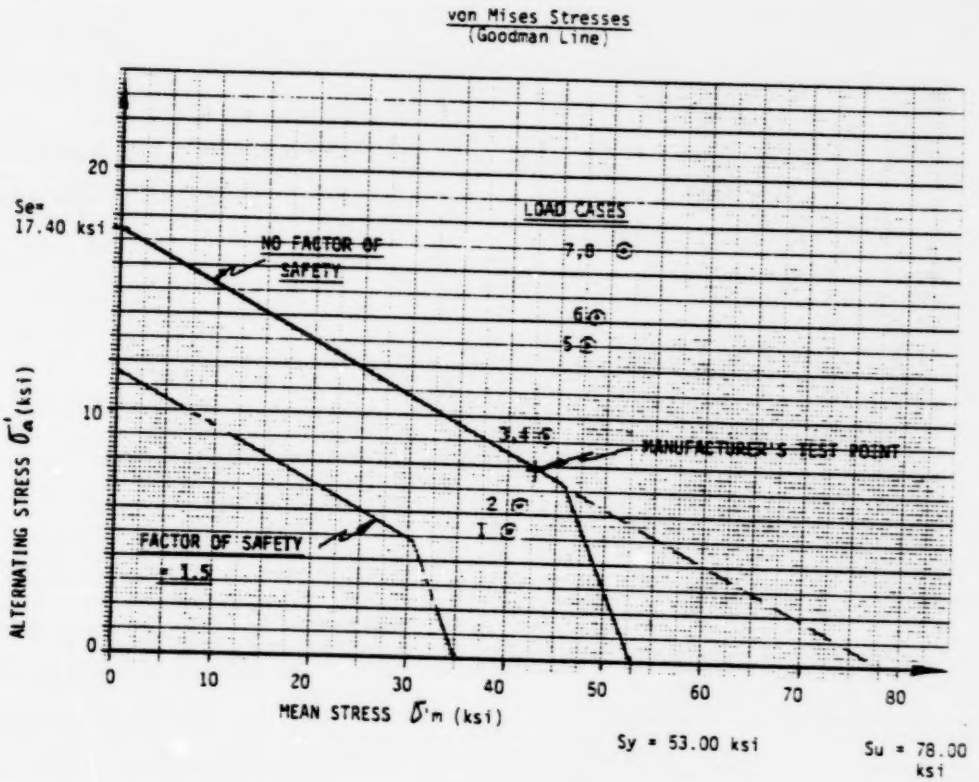


FIGURE 12: STRESS RESULTS

15,100 psi, all of the load cases were re-calculated using this corrected model for bending stress and the resulting von Mises stresses were recorded as corrected mean and alternating stresses in Table 4 as σ_m' and σ_a' respectively.

4.3 STRESS RESULTS

In order to better model the actual stress levels in the wheel hub, both the uncorrected and corrected stress results appear in Table 4. The uncorrected stress results are based on the initial estimate of the bending stress 'σ_r' as outlined in paragraph 4.2.1. The corrected stress results are based on the modified estimate of 'σ_r' as defined in paragraph 4.2.7 above.

The resulting corrected von Mises stresses σ_m' and σ_a' are plotted on the Goodman Line developed earlier and shown in Figure 12, providing a good comparison to the derived component strength.

When no factor of safety is applied, only the load cases 1 and 2 allow infinite life, but these load cases represent ideal conditions of perfect track with no dynamic input whatsoever. The best factor of safety resulting from this analysis is for load case 1 and is only marginal (i.e., F.S. = 1.14).

When a reasonable factor of safety (FS = 1.5) is applied to the failure criteria, (Goodman Line) it can be seen that none of the load cases will safely allow an infinite fatigue life of the wheel hub.

It is clear that the absolute magnitude of the corrected stress results is probably very close to reality, revealing the severity of the overstressed condition of the wheel hub.

4.4 LIFE ANALYSIS

An S-N curve is plotted in Figure 13 based on Reference 3. The corrected alternating stress (σ_a') levels of Table 4 are multiplied by two to obtain the stress range, and then multiplied by a stress concentration factor K_f of 1.76 determined from Reference 5 Figure 159 (K_{tg}) and adjusted for notch sensitivity by the following expression:

$K_f = 1 + q\,(k_{tg} - 1)$ (Reference 3, Page 194)

This stress concentration factor K_{tg} takes account of both loss of section and geometry effects.

No other factors including safety factors are applied to the stress range values. The stress range values are listed in Table 5 and the percent life utilized is indicated where appropriate. The finite life cycles allowed for each load case was determined from the S-N curve in Figure 13.

To determine the actual expected life of the wheel hub, the following calculation is made:

$$\text{Actual Life} = 5000 \times \frac{100\%\ \text{Life}}{\%\ \text{Life Utilized}}$$

$$= 5000 \times \frac{100}{1977}$$

Actual Life = 253 miles

These analyses are, however, very difficult to carry out precisely because of the assumptions needed and therefore should not be used to precisely define fatigue life. Rather, they should be used to indicate, as in this case, that drastically reduced life can be expected. Since no safety factors were applied, even this short life is questionable.

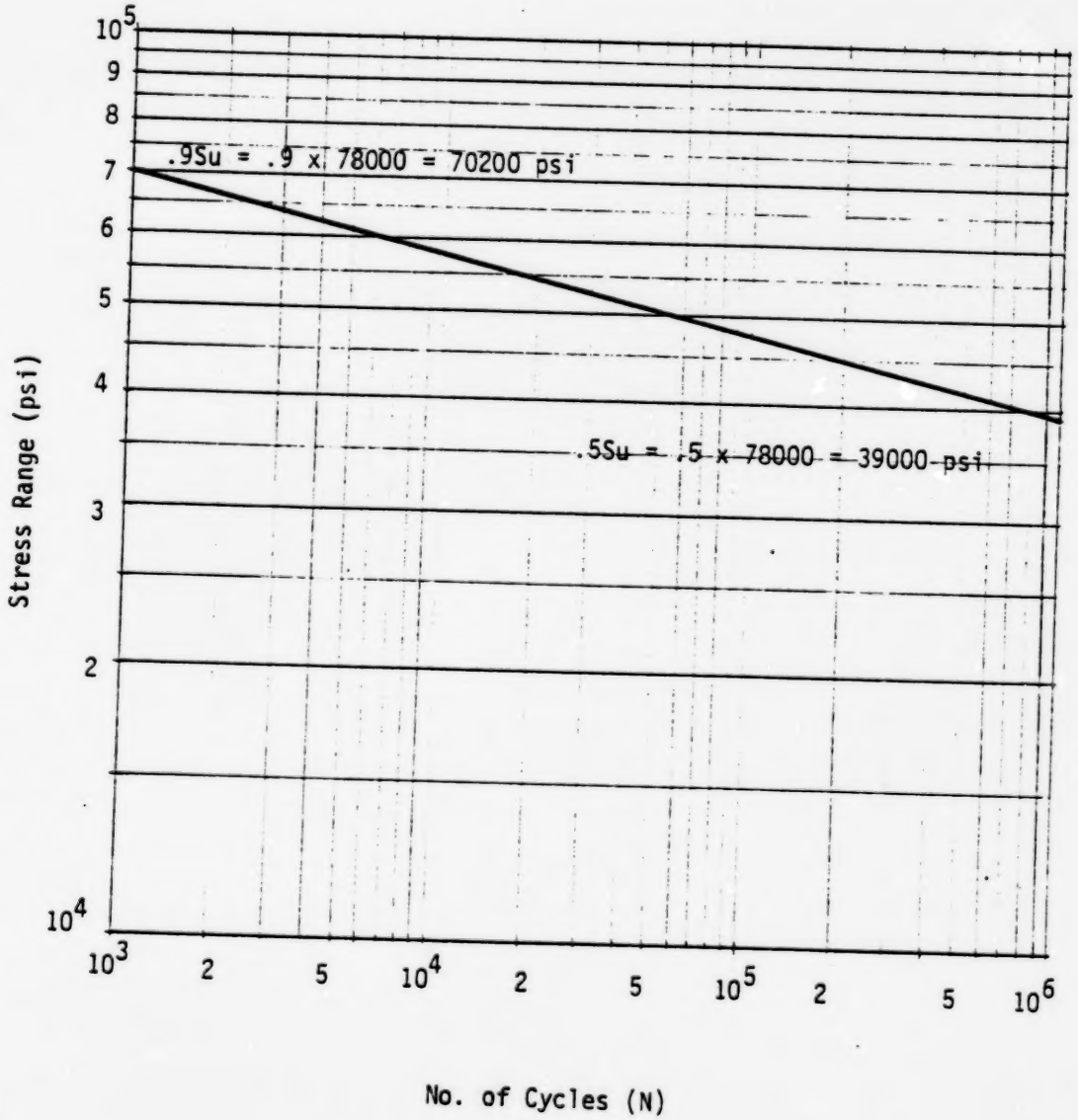


FIGURE 13: S-N CURVE

TABLE 5

LIFE CYCLE ANALYSIS

LOAD CASE	CORRECTED ALTERNATING STRESS σ_a' (psi)	FACTORED STRESS RANGE (psi)	FREQUENCY OF OCCURANCE IN 5000 MILES	* N CYCLES	PERCENT AVAILABLE LIFE UTILIZED
1	± 5278	18585	2.30×10^6	∞	Nil
2	± 6383	22475	$.53 \times 10^6$	∞	Nil
3	± 9212	32437	$.55 \times 10^6$	∞	Nil
4	± 9212	32437	$.13 \times 10^6$	∞	Nil
5	± 13125	46215	1.01×10^6	140000	721%
6	± 14199	49996	$.24 \times 10^6$	55000	436%
7	± 17025	59947	$.04 \times 10^6$	6100	656%
8	± 17025	59947	$.01 \times 10^6$	6100	164%
				TOTAL	1977%

* Determined from Figure 13

a UTDC Company

5.0 CONCLUSIONS

It is clear from the stress analysis results, that the wheel hub is overstressed to the point of severely restricting the life of the wheel hub. Even load cases 1 and 2, which represent perfect track conditions, are not acceptable simply because an insufficient factor of safety exists to account for such unknowns as:

- wheel previous history
- method of torquing wheel nuts
- material surface condition due to age
- precise wheel load case definitions
- inaccuracies in stress model predictions
- unknown material flaws

To obtain a measure of the significance of the above factors one should take into consideration some of the following facts.

o With respect to the wheel hub history, it is known that all of the wheel hubs were modified from second-hand road wheel hubs. In fact a date of 1963 was found on one of the wheel hubs. It is estimated that the age of the wheel hubs used for the Railbus is approximately 20 years. During the previous history of the wheel hubs, any number of over-stress loads may have occurred resulting in a reduced fatigue life and perhaps initiating microscopic cracks.

o The modified wheel hubs should always be installed according to the recognized procedure of alternate torquing of wheel nuts. In fact when reviewed later, it was determined that the wheel nuts had not always been torqued alternately, and that pneumatic wrenches were sometimes used rather than a torque wrench. This was corroborated later when wheel nut torques were checked, indicating excessive torque on some of the wheel nuts.

- The surface condition of the wheels indicated significant corrosion and pitting of the wheel hub as well as varying levels of scoring of the wheel nut seats.

- The inaccuracies in the load case definitions, the inaccuracies in the stress model predictions, and the unknown material flaws are usual types of unknowns which should be considered in every design. The usual factor applied to the latter three unknowns including a confidence factor is in the order of 1.5 for fatigue type loading.

The estimated wheel life of 253 miles although apparently significantly less than the 5002 miles actually travelled at the time of the wheel failure is not an unreasonable prediction considering the conservatism of the technique used and the fact that cracking of the wheel may have been initiated many miles before the complete failure occurred.

The high stress levels as well as the low finite life cycles allowed indicates that the probable failure mode can be identified as low cycle fatigue. The usual effect on the base material with this type of failure includes local work hardening resulting in the material behaving more as a brittle material than ductile material. This could explain why only a few miles before the wheel failure occurred, the wheels had been visually inspected with no evidence of cracking. The resulting failure thus may have followed the typical scenario of catastrophic failure for brittle materials.

As a result of this analysis, it is concluded that the vehicle cannot be operated safely with the current wheel design and must be withdrawn from service. The use of new rather than used wheels of the same design would not have changed this conclusion.

6.0 RECOMMENDATIONS

The following steps would be required as a minimum to re-establish passenger service with the WCSS vehicle:

- Redesign the wheel hub for the WCSS Railbus with a minimum of parallel changes to the rest of the vehicle;
- Calculate results of wheel changes on other bus components such as wheel bearings;
- Fabricate sample wheel;
- Fatigue test sample wheel on test rig;
- If life cycle targets are met, fabricate a set of wheels and spares;
- Retest wheels on railbus in non-passenger service including:
  - dynamics, switching, curving
  - ride
  - noise and vibration
  - axle loads
- Assess and review modification with TDC and gain CN, CTC approval; and
- Return vehicle to non-revenue passenger service.

The minimum change solution to provide a sound suspension and wheelset for the railbus involves significantly more than just the design of a new wheel hub for WCSS 001. Invariably any new wheel hub design, whether based on a heavier standard road wheel or designed from scratch, would result in a stiffer "primary" suspension. This would result in higher dynamic loads on the bearings, axles, suspension components and possibly the bus body. All of these factors would have to be analyzed to determine the overall impact on the integrity of WCSS 001.

All of these factors considered, this minimum change solution is anticipated to be technically feasible, but will result in a limited life of axles, bearings, and suspension components.

7.0 REFERENCES

1) AII TTL, Report No. 338-610-002, Appendix A.

2) "Formulas for Stress and Strain", Fifth Edition, Roark and Young, McGraw-Hill Book Company, 1975.

3) "Mechanical Engineering Design", Third Edition, Joseph Edward Shigley, McGraw-Hill Book Co., 1977.

4) "Engineering Considerations of Stress, Strain and Strength", Robert C. Juvinall, McGraw-Hill Book Co., 1967.

5) "Stress Concentration Factors", R.E. Peterson, John Wiley and Sons Inc., 1974.

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UTDC

9 September 1986

Ref.: TTL/1651/86

Transport Canada
Transportation Development Centre
Complex Guy Favreau
200 Dorchester West
Suite 601, West Tower
Montreal, Quebec
H2Z 1X4

Attention: Mr. Sesto Vespa

Dear Mr. Vespa:

Subject: Contract For: Winter Testing and Passenger Demonstration of WCSS Railbus on CN Line
DSS File No. 14SD.T8200-5-5562
Contract Serial No. 0SD85-00272

Following the many delays and difficulties on this project which have been reported to you previously, unanticipated vehicle structure failures occurred on August 30, 1986 which have again caused the subject test program to be stopped. In this incident, the WCSS 001 railbus, designed and manufactured by subcontractors to DSS/TDC prior to TTL being involved, experienced a critical failure with its wheels. TTL staff, by timely action, fortunately avoided a potential derailment with 14 passengers aboard. TTL has taken emergency action in order to accommodate stranded passengers, analyze the problem and effect those repairs necessary to permit return of the vehicle to Thompson, Manitoba. The vehicle is now disabled and requires significant testing to ensure passenger safety if it is to operate again.

The following is a summary of the emergency actions taken by TTL:

A) On Saturday, August 30, at approximately 10 a.m. the left front wheel of the WCSS 001 Railbus prototype failed. The TTL train rider noticed a change in noise and vibration levels and alerted the CN crew to bring the vehicle to a full stop in order to determine the source of the problem and if it represented a concern for the safety of the 14 passengers and crew.

Upon examination it was observed that the left front wheel had severe cracking around the mounting studs and would have failed completely if the vehicle had been allowed to continue its journey. Inspection by TTL of the remaining vehicle wheels revealed the possibility of a problem with the right front wheel.

B) On Saturday August 30, the following further emergency actions were taken:

1. The passengers were returned to Thicket Portage by local All Terrain Vehicle (ATV) transportation (approximately 3 miles).

2. The CN Auxiliary at The Pas was called out to retrieve the vehicle.

3. The local CN Roadmaster, off-duty at the time, responded to radio discussions between TTL & CN. He attended the site on his own initiative and suggested an alternative means of vehicle retrieval based on freight car experience.

   The technique utilized for the vehicle retrieval involved placing a railroad tie below the pilot which supported most of the weight normally carried by the front wheels. The wheel flanges remained sufficiently engaged with the track to provide guidance.

   Permission was obtained from CN Operations and TTL management to use the suggested technique.

4. The CN auxiliary crew requested earlier was cancelled.

5. The vehicle was driven slowly under its own power to Thicket Portage and stored on a siding.

6. After performing further inspection and taking photographs of the failure, the CN crew and TTL train rider were returned to Thompson.

7. An attempt by TTL (J.H. Stannard) was made to contact the TDC, Project Officer (S. Vespa).

C) On Sunday, August 31 and Monday, September 1, teleconferences were held between TTL management and site personnel to determine items requiring immediate action. In addition, the four spare wheels delivered to INCO at Thompson were located and the services of an INCO technician familiar with the vehicle was arranged.

D) On Tuesday, September 2 following Labour Day, the following actions were taken:

1. TDC was notified by telecon (Sesto Vespa) of the emergency and TDC agreed to unofficially notify CTC.

2. The vehicle status was discussed by telecon with CN Winnipeg (Bruce Rice, Gary Holden) and the CN crew requirement was cancelled.

3. Inspection reports and general data on the wheels, axles and studs were reviewed by engineering at TTL, Kingston.

4. The four spare wheels were sandblasted, inspected and crack tested at Thompson by TTL and INCO employees. One wheel was rejected on the basis of prior damage to mounting holes. One wheel was rejected based on cracking around mounting holes. The two remaining wheels were judged to be acceptable for at least the 45 mile return trip to Thompson (without passengers).

E) On Wednesday, September 3, the following actions were taken:

1. CANAC was notified by telex and CANAC in turn officially notified the CTC of the failure.

2. A support frame for changing wheels in the field was constructed by INCO under TTL direction.

3. Preparations were made by TTL to ship tools, spares and the support frame from Thompson to Thicket Portage.

4. The history of the wheels (which were part of the vehicle designed and manufactured by TDC subcontractors(s) prior to TTL involvement in the Project) was studied and potential causes for failure identified.

5. The manufacturer (Firestone) of the original bus wheels which had been modified for rail use was contacted with respect to ascertaining the original wheel design loads.

6. TDC was notified by telecon and verbal agreement received from Sesto Vespa to proceed with the current actions and undertakings identified by TTL.

F) On Thursday, September 4, the following actions were taken:

1. A TTL engineer travelled to Thompson for on-site inspection in order to prepare a proper incident report for TDC, CN, CANAC, and CTC.

2. WCSS provided TTL with spare mounting studs on an emergency request basis.

G) The above actions were undertaken by TTL on an emergency basis and the following course of action, as discussed and agreed with TDC (S. Vespa), is in process.

1. Complete on-site emergency repair and return WCSS 001 railbus to Thompson where more thorough investigation can be carried out.

2. Prepare and issue incident report including an analysis of the failure, and recommendations (if any) for corrective action.

3. Identify action(s) undertaken by TTL based on results of 2.

TTL requests timely approval for the actions which have been undertaken as well as their associated costs (Ref. to Attachment 'A') under "emergency repairs" in the subject contract.

Regards,

TRANSPORTATION TECHNOLOGY LIMITED

J.H. Stannard
Program Manager

Attach.

cc: Ms. D. Favreau - DSS

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